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DWORSHAK KOKANEE POPULATION AND ENTRAINMENT ASSESSMENT

2006 ANNUAL REPORT
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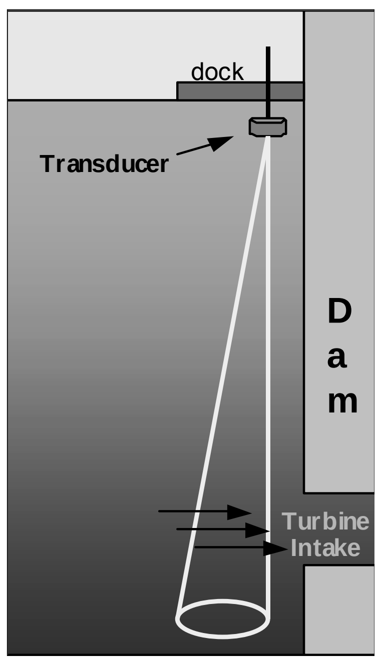

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IDFG Report Number 08-17
November 2008

DWORSHAK KOKANEE POPULATION AND ENTRAINMENT ASSESSMENT

Project Progress Report

2006 Annual Report

By

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To

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ABSTRACT

During this contract, we continued testing underwater strobe lights to determine their effectiveness at repelling kokanee *Oncorhynchus nerka* away from Dworshak Dam. Strobe light tests were conducted on four nights from April 24-27, 2006, in front of the middle reservoir outlet (RO) 2. The density and distribution of fish, (thought to be mostly kokanee), were monitored with a split-beam echo sounder. We then compared fish counts and densities during nights when the lights were flashing to counts and densities during adjacent nights without the lights on. On two nights, April 25 and 27, 2006, when no lights were present, fish counts near RO 2 averaged 12.4 fish and densities averaged 31.0 fish/ha. When strobe lights were turned on during the nights of April 24 and 26, mean counts dropped to 4.7 fish and densities dropped to 0.5 fish/ha. The decline in counts (62%) and densities (99%) was statistically significant ($p = 0.009$ and 0.002, respectively). Test results indicated that strobe lights were able to reduce fish densities by at least 50% in front of a discharging reservoir outlet, which would be sufficient to improve sport fish harvest.

We also used split-beam hydroacoustics to monitor the kokanee population in Dworshak Reservoir during 2006. Estimated abundance of kokanee increased from the 2005 population estimate. Based on hydroacoustic surveys, we estimated approximately 5,815,000 kokanee (90% CI ± 27.6%) in Dworshak Reservoir in August 2006. This included 2,183,000 age-0 (90% CI ± 24.2%), 1,509,000 age-1 (90% CI ± 29.0%), and 2,124,000 age-2 (90% CI ± 27.6%) kokanee. This resulted in a density of age-2 kokanee above the management goal of 30-50 adults/ha.

Entrainment sampling was conducted with fixed-site, split-beam hydroacoustics from May through September for a continuous 24 h period when dam operations permitted. The highest fish detection rates from entrainment assessments were found during dawn periods, unlike previous year's results, which were highest during nighttime. The lowest detection rate was found during the day period, which was consistent with previous findings. Fish detection rates were generally low during high discharges throughout the summer and highest during low discharges in May and June. Low detection rates were found during high discharge periods during drawdowns for anadromous fish flows in July and August, which resulted in low susceptibility to entrainment.

Counts of spawning kokanee in four tributary streams totaled 29,743 fish. These data fit the previously developed relationship between spawner counts and adult kokanee abundance in the reservoir.

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INTRODUCTION

Fisheries for kokanee *Oncorhynchus nerka* in the Pacific Northwest are very popular (Wydoski and Bennett 1981; Rieman and Myers 1992). Kokanee feed low on the food chain and may reach densities in excess of 150 harvestable-sized fish/ha even in relatively sterile waters (Maiolie et al. 1991). They also appear to be an ideal fish in fluctuating reservoirs since they rear in the open pelagic zone, and some strains spawn in tributary streams away from the potential impacts of water level fluctuations. When densities of kokanee are high, Dworshak Reservoir becomes one of the best kokanee fisheries in the state, accounting for a harvest of over 200,000 fish annually.

Kokanee, however, can exhibit behavioral tendencies to school and emigrate resulting in potentially large entrainment losses. Entrainment losses have been documented in Libby Reservoir in Montana (Skarr et al. 1996), Banks Lake, Washington (Stober et al. 1979), and Dworshak Reservoir (Maiolie and Elam 1998). At Dworshak Reservoir, it was estimated that 1.4 million kokanee (95% of the population) were lost through the dam in a period of 5 months in 1996 (Maiolie and Elam 1998).

Thus, entrainment loss of kokanee has been established as the single most important factor contributing to variability in the population. In 1996, losses of kokanee were severe enough that they strongly affected the angler success in subsequent years. Years with high discharge have correlated with lower kokanee populations in the reservoir (Maiolie and Elam 1993). Therefore, a major task of this project during this contract period was to assess fish susceptibility to entrainment under varying discharge, pool elevation, water clarity, and other variables.

This report describes the ongoing assessment of Dworshak Reservoir kokanee including effectiveness testing of underwater strobe lights to deter kokanee away from dam intakes, entrainment assessment, and kokanee age, growth, and density. During this contract, hydroacoustic surveys were used to assess the effectiveness of strobe lights to reduce kokanee densities in front of a discharging turbine and to quantify the abundance and density of kokanee in the reservoir. Results from these surveys were used to determine the effects of the water year, changes in seasonal dam operation (discharge), and drawdowns for anadromous fish flows on the kokanee population in comparison to the available long-term abundance, density, and length-at-age data. We also assessed the diel and seasonal susceptibility of kokanee to entrainment through dam intakes in relation to water discharge.

OBJECTIVE

To maintain densities of 30 to 50 adult (age-2 and older) kokanee/ha in Dworshak Reservoir by reducing entrainment losses.

STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River in northern Idaho. At 219 m tall, it is the tallest straight-axis concrete dam in the United States. It was built in 1971 by the U.S. Army Corps of Engineers (USACE) for power production and flood control. Three turbines within the dam have a total operating capacity of 450 megawatts. The dam can discharge up to 380 m^3/s (10,000 cfs) through the turbines and an additional 420 m^3/s (15,000 cfs) through reservoir outlets and the spillway.

Dworshak Reservoir is 86 km long at full pool (Figure 1). Maximum and mean depths are 194 m and 56 m, respectively. Surface area at full pool is 6,644 ha with 5,400 ha of kokanee habitat (defined as the area over 15 m deep). Drawdowns for flood control may lower the surface elevation 47 m and reduce surface area by as much as 52%. The reservoir has a mean hydraulic retention time of 10.2 months and a mean annual discharge of 162 m^3/s (Falter 1982). High releases from the reservoir occur during spring runoff, during the fall when the reservoir is lowered for flood control, and during late summer when water is released for anadromous fish flows.

Kokanee were first stocked into Dworshak Reservoir in 1972 (Horton 1981). Four sources of fish were initially used, but the early spawning strain from Anderson Ranch Reservoir, Idaho now populates the reservoir (Winans et al. 1996). These fish spawn during September in tributary streams as far as 140 km above the reservoir. They reach maturity primarily at age-2, although age-1 and age-3 spawners were occasionally found. Adults range in size from 200 to 400 mm in total length depending on the density of fish in the reservoir, but generally average 300 mm during spawning (Maiolie and Elam 1995).

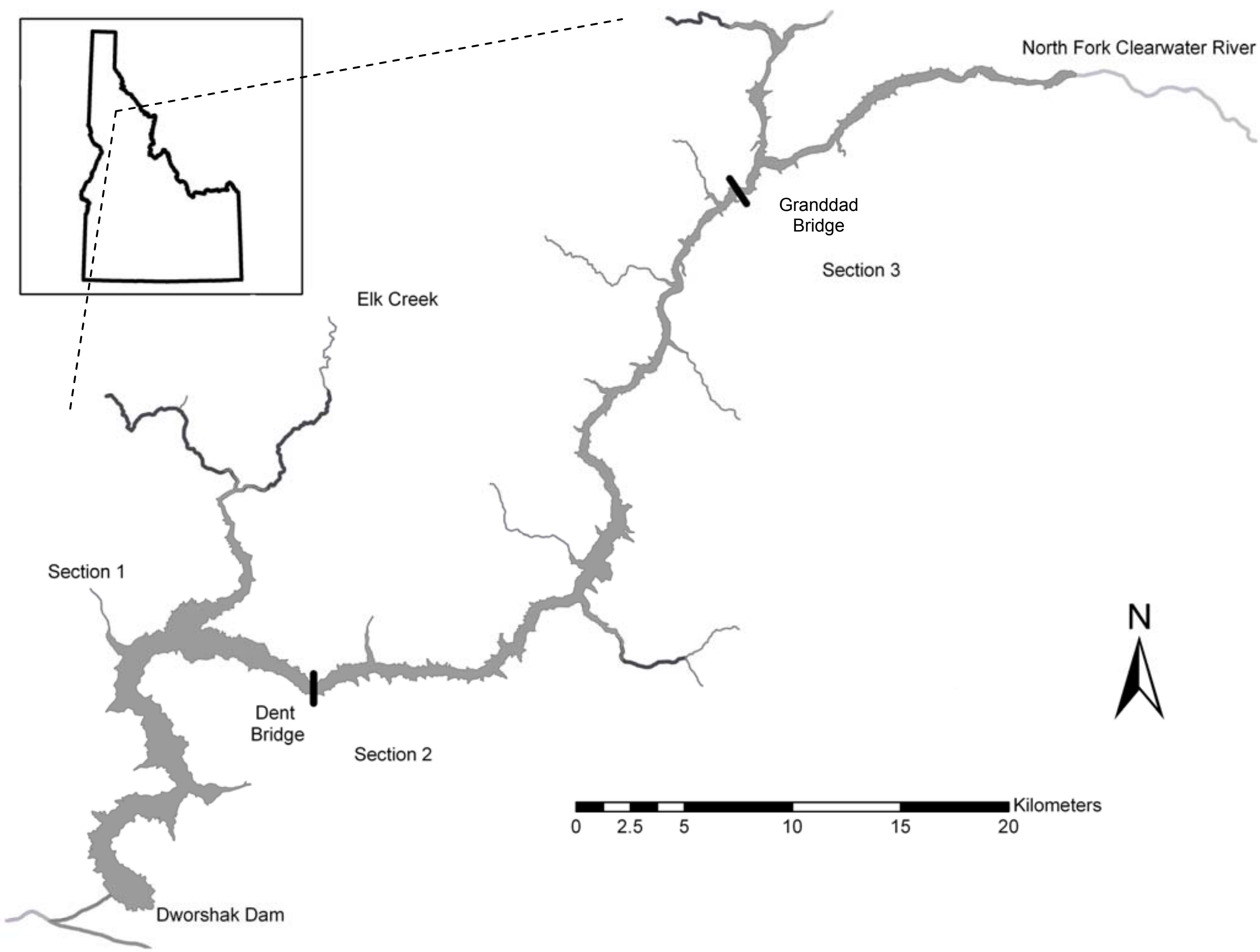

Figure 1. Map of Dworshak Reservoir and its major tributaries and reservoir sections, North Fork Clearwater River, Idaho.

METHODS

Strobe Light Testing

Strobe light tests were conducted on four nights from April 24-27, 2006, in front of the middle reservoir outlet (RO) 2. Mean discharge through RO 2 was 102 m^3/s during the tests but varied from 96 m^3/s to 105 m^3/s (Table 1). Reservoir outlets are used for additional evacuation of water once the maximum total turbine discharge has been reached, which occurred during the test period. ROs 1 and 3 were not utilized during this period. Control samples were nights with no strobe lights flashing, and test samples were nights strobe lights were deployed and flashing. A random selection (coin flip) was used to determine which sample (test or control) occurred first for each two consecutive night period (paired replicate).

One strobe light system was used during these tests in front of RO 2. The strobe system consisted of nine individual lights, with two whorls of four lights and a single light pointed directly downward from the lower whorl of lights. Lights in each whorl were pointed horizontally and were positioned 90° from each other. Lights were raised and lowered on a 6.4 mm steel cable using a 3600 kg vehicle winch.

Reservoir outlets one and three were not operated; water was only discharged through RO 2 during the test periods. Also, throughout the test periods the top whorl, bottom whorl, and down-pointing light were positioned at 41.8, 47.9, and 48.8 m deep, respectively. The top whorl, bottom whorl, and down-pointing light lights were 8.5, 2.4, and 1.5 m above the top of reservoir outlet opening, respectively. All lights flashed simultaneously at 360 flashes/min. During testing, the reservoir pool elevation ranged from 468.0 to 468.2 m above mean sea level (MSL).

Each hour throughout the night from approximately 21:00 to 05:00 h a single hydroacoustic survey transect was conducted parallel with the face of the dam, about 5-10 m out into the reservoir (Figure 2). Hydroacoustic surveys were conducted with a BioSonics™, Inc. DE-X split-beam scientific echo sounder with a 201 kHz transducer. We calibrated the echo sounder at the beginning of the year using a 23 mm copper calibration sphere with a target strength (TS) of -40.4 decibels (dB). We checked the calibration of the echo sounder prior to each strobe light testing and adjusted the transducer gains if needed. Boat speed during transects averaged 1.1 m/s. Secchi disc transparencies were also measured each day of the testing to relate strobe light effectiveness to water clarity.

We analyzed the data from each hydroacoustic transect to detect fish in an area from 20 to 80 m deep and 60 m wide (30 m on either side of the lights) directly upstream of the discharging RO. The number of fish detections and subsequent densities were calculated using SonarData Echoview™ 3.5 hydroacoustic analysis software. We configured the Echoview analysis settings so that only echoes meeting certain criteria would be considered as a fish, thereby eliminating turbine noise from the echograms and subsequent analyses. We used a minimum TS threshold of -45 dB, so only echoes larger than -45 dB in TS (a fish 97 mm total length based on Love [1971]) were included in the analyses. The maximum beam compensation was set at 6.0 dB, and we used Echoview minimum and maximum normalized pulse lengths of 0.3 and 1.8 respectively.

Table 1. Experimental design (replicates and treatments) and reservoir conditions during four nights of strobe light testing in front of Dworshak Dam, April 24-27, 2006. Mean Discharge rates are for Reservoir Outlet (RO) 2, which was the only RO operating during the experiment.

Date	Replicate	Treatment (Control / Test)	Mean Discharge (m^3/s)	Pool Elevation (m above MSL)
Apr 24	1	Test	104.8	468.2
Apr 25	1	Control	102.8	468.1
Apr 26	2	Test	101.1	468.0
Apr 27	2	Control	101.6	468.0
		Min	**96.3**	**468.0**
		Mean	**102.2**	**468.1**
		Max	**104.8**	**468.2**

In addition to the aforementioned echo criteria, we used the following track acceptance criteria. We required a minimum of three single target detections, a minimum of three pings, and a maximum of one missing ping per track to qualify targets as a fish track. Manual counting of fish tracks meeting both the echo and track criteria was conducted on each transect file again using SonarData Echoview™ 3.5 software. Echoes meeting the above criteria were counted as a single fish.

Estimates of both numbers of fish and fish densities (fish/ha) in hourly transects were averaged for the entire night to comprise one sample. We then used SYSTAT™ version 11.0 to run a Kruskal-Wallis ANOVA with a Mann-Whitney U-test of control versus test samples to determine if differences in fish numbers and densities existed. Differences were considered significant if $p < 0.05$. Strobe lights were determined effective if they were able to reduce fish densities by at least 50%.

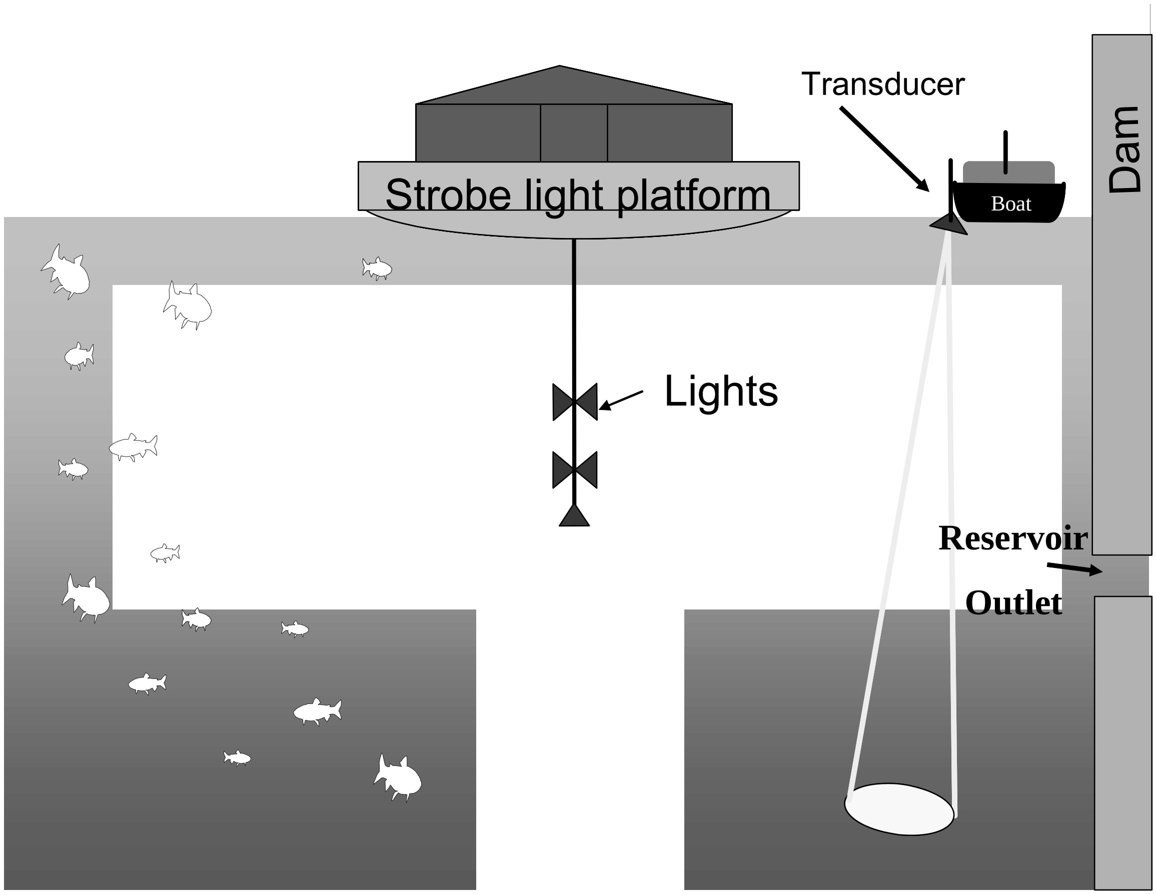

Figure 2. Diagram of strobe light and hydroacoustic equipment setup during testing to deter kokanee away from discharging reservoir outlet of Dworshak Dam, Idaho.

Lastly, the distance (m) from the strobe lights to the nearest fish in each of three directions: left or right (laterally) and below the lights was calculated. Lateral distances were calculated by multiplying the number of pings between the fish and the strobe lights, times the ping rate (pings/s), and then multiplying by the boat speed for each transect. Again, we performed a Kruskal-Wallis ANOVA with a Mann-Whitney U-test using SYSTAT to determine if there was a statistical difference in the distance fish were deterred in control transects versus test transects. Differences were considered significant if $p < 0.05$.

Kokanee Population Estimate

A standardized hydroacoustic survey was conducted to estimate kokanee abundance and density in Dworshak Reservoir on the evenings of August 1st, 2nd, and 3rd. The reservoir was stratified into three sections: from the dam to Dent Bridge; Dent Bridge to Granddad Bridge; and Granddad Bridge to the slack water area (Figure 1); and a stratified systematic sampling scheme was used to estimate kokanee abundance and density. Survey transects were conducted in a zigzag fashion from one side of the reservoir to the other, with one transect starting where the previous transect ended, up the length of the reservoir.

We used a Simrad™, Inc. EY-500 split-beam scientific echo sounder with a 120 kHz transducer to document the abundance and distribution of kokanee. We calibrated the echo sounder at the beginning of the year using a 23 mm copper calibration sphere with a target strength (TS) of -40.4 decibels (dB). We checked the calibration of the echo sounder prior to each survey night and adjusted the transducer gains if needed. Boat speed during hydroacoustic transects averaged 1.5 m/s. The echo sounder was set to ping at 1.0 s intervals, with a pulse width of 0.3 milliseconds. Data were collected with a time varied gain constant of 20 log r (range).

During post processing of echograms we used analysis settings that only included echoes meeting certain criteria to be regarded as a fish, thereby eliminating any noise from echograms and subsequent analyses. We used a maximum beam compensation of 6.0 dB and minimum and maximum normalized pulse lengths of 0.3 and 1.8, respectively. Fish density estimates were calculated using SonarData Echoview™ 3.5. Densities were estimated by echo integration techniques to account for fish within schools that could not be distinguished as single targets. We analyzed only the pelagic region of each echogram, from depths of 10 m to 40 m. These depths correspond to the distribution of kokanee in the water column.

Scales were collected from both angler caught and trawl caught kokanee in 2006 to verify lengths of kokanee within each age class. Scales were collected dorsally to the lateral line and posterior to the dorsal fin using techniques described by Nielsen and Johnson (1985). Using a blunt knife, scales were loosened by scraping toward the head. Six to twelve scales were collected from each fish and sealed in a coin envelope labeled with total length (TL) and date collected. Scales were prepared by pressing them between two acetate slides. The slides were then viewed using a microfiche reader to examine patterns of growth from impressions of the scales on the slides. Areas of relatively slower growth signifying each winter season or the end of one year's growth (annuli) were counted to determine age. These aging techniques are described by Nielsen and Johnson (1985).

We then graphed a frequency distribution of fish target strengths (TS) from the survey transects. Then, TL age class breaks from angler and trawl caught kokanee were transformed using Love's (1971) equation to approximate the acoustic TS (-dB) age class breaks. These age class breaks were subsequently used to generate age-specific abundance and density estimates.

During sampling, the reservoir elevation varied from 476.8 to 477.6 m (1,564.3 ft - 1,566.9 ft) with a weighted mean of 477.0 m (1565.0 ft), and the midpoint of the kokanee layer was about 23.1 m deep (75.8 ft). Therefore, we used an area of 4,387 ha of kokanee habitat corresponding to an elevation of 453.8 m (1,489 ft).

Mean density of each age class of kokanee in each reservoir section was calculated and multiplied by the area of that section to obtain abundance estimates per reservoir section. Abundance estimates for each reservoir section were totaled to obtain total age class population estimates and the age class estimates totaled to obtain total kokanee abundance in the entire reservoir. Ninety percent confidence intervals were calculated on the age-0, age-1, age-2, and total kokanee abundance estimates using a formula for stratified systematic designs (Scheaffer et al. 1990).

Entrainment

Entrainment sampling was conducted a minimum of two days per month (each for a continuous 24 h period) when the forebay area was accessible. This monitoring provided baseline information on time of day fish were susceptible to entrainment; detection rate immediately in front of the different turbine units and reservoir outlets; and the degree of variability in fish susceptibility that can be expected between the time of day, seasons, and discharge rate. Secchi disc transparencies were also measured during most hydroacoustic sample periods. These were used to relate water clarity to discharge rate and entrainment susceptibility.

A wooden dock was secured to the trashracks of the turbine to be sampled (Figure 3). The hydroacoustic equipment was set up under the protection of a tent, which was attached to the dock. The echo sounder's transducer was attached to a pole, which was secured to the dock and pointed between 1° and 5° from vertical, outward from the face of the dam. This angle was adjusted for each sampling period depending upon the pool elevation and selector gate mode and depth. The outward angle and distance from the face of the dam were set to maximize the echogram coverage of the turbine opening yet still ensure that return echoes from the face of the dam did not interfere with detecting fish targets.

During sample periods when turbines were discharging in 'overshot mode' (meaning the selector gate was lowered in front of the turbine unit opening, and water flows over the top of the gate), only fish echoes in a zone from approximately 10.0 m above to 5.0 m below (15.0 m tall zone) the selector gate's top were counted. During sample periods when turbines were discharging in 'undershot mode', meaning the selector gate was raised allowing water to flow straight into the turbine unit opening, only fish echoes within the depths of the opening were counted. The intake openings for turbine units 1 and 2 are located between 429.2 and 437.4 meters above MSL, which results in an 8.2 m analysis zone when the turbines are operating in undershot. The opening for turbine units 3 is located between 425.2 and 437.4 meters above MSL, which results in a 12.2 m analysis zone when unit 3 is operating in undershot. The center of the analysis zone was considered the depth of the selector gate if in overshot mode, or the center of the turbine opening (penstock) if in undershot mode.

We used the above echo sounder placement and sampling methods to estimate hourly rate of kokanee detection immediately in front of a single operating turbine unit or reservoir outlet. A BioSonics, Inc. DE-X™ split-beam scientific echo sounder with a 201 kHz transducer was used for all entrainment assessment sampling. The echo sounder was professionally calibrated by the manufacturer prior to the start sampling in March 2004. Then, prior to each sample period, we checked the calibration of the echo sounder by measuring the target strength (TS) of a 36 mm diameter standard calibration sphere, compared the TS against the known TS of the sphere at the sample water temperature, and adjusted the transducer gains if needed.

The echo sounder was set to ping at 5 pings per second with a pulse width of 0.3 milliseconds. The maximum beam compensation was set at 6.0 dB. In addition, the returned echo had to be greater than -45 dB (>100 mm, Love 1971) to be counted as a valid fish echo. This minimum threshold was necessary to avoid detection of echoes returning from the face of the dam, which would interfere with detection of small fish.

Further criteria were applied and analysis of fish echoes was then conducted on each hydroacoustic file using SonarData Echoview™ 3.5. We used Echoview minimum and maximum normalized pulse lengths of 0.3 and 1.8, respectively. We then manually counted fish echoes meeting the following track recognition criteria. We required a minimum of three single target detections, a minimum of three pings, and a maximum of one missing ping per track to qualify targets as a fish track. Fish tracks meeting these track criteria were counted as a single fish.

We divided the total number of fish detected by the number of hours sampled to estimate a detection rate (fish/h). This was determined for each of four time strata (dawn, day, dusk, and night). The diameter of the beam (B) at the depth of the center of the intake opening was also calculated with the following equation.

$$\text{Beam diameter (B)} = 2 \times R \times [\,\text{Tan}\,(\,\theta / 2\,)\,]$$

Where: R = range (depth of intake opening)
Tan = tangent of the angle
θ = the nominal beam width
(6.6 degrees for the 201 kHz transducer)

The portion (%) of the intake sampled was calculated by dividing the diameter of the beam (B) by the width of the turbine opening (I). The original detection estimates were then expanded upon based on the percent coverage of the acoustic beam during each sample period, respectively.

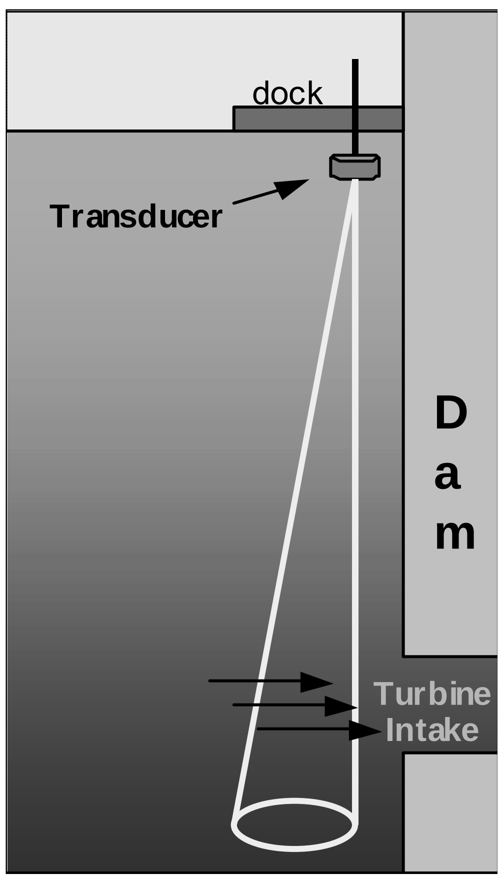

Figure 3. Location of the fixed-site echo sounding gear used to detect fish to determine their susceptibility to entrainment into turbine units and reservoir outlets of Dworshak Dam, Idaho.

Discharge

Data on daily discharge, pool elevation, turbine units operating, reservoir outlets in use, and spillway operation for the year were obtained from the USACE Dworshak Project Control Room. The timing and magnitude of discharge from Dworshak Dam was used to examine correlations between entrainment potential and population abundances. All discharge values were measured in thousand cubic feet per second and were then converted to the metric unit of cubic meters per second (m^3/s). Pool elevation was measured as meters above MSL.

Spawner Counts

We counted kokanee in four tributaries to the North Fork of Clearwater upstream of Dworshak Reservoir on September 28, 2006. These spawner counts serve as an additional relative index of the adult population abundance. Spawning kokanee were counted in Isabella Creek, Dog Creek, Skull Creek, and Quartz Creek. Streams were walked from their mouths to the furthest upstream reaches utilized by kokanee. These index tributaries have been surveyed annually since 1981 on or near September 25, which was determined to be the peak of kokanee spawning (Horton 1980). The total length (TL) of available dead or near dead kokanee was also measured to obtain an adult spawner length distribution.

RESULTS

Strobe Light Testing

Fish distribution near RO 2 was noticeably different on nights when the strobe lights were flashing versus nights without the lights on (Table 2). When the lights were off, kokanee were scattered from approximately 5.0 to 80.0 m deep near the face of the dam directly in front of the discharging RO. On nights when the lights were on, kokanee in the area near the turbines were far fewer in number and were repelled an average of 65 m from the lights (Table 2).

Fish counts (tracks) near RO 2 were highly variable between hourly samples of both control and test acoustic samples, yet counts were reduced when strobe lights were on compared to when turned off (Figure 4). Control samples had fish counts from zero up to 33 fish, whereas test samples ranged from zero to 19 fish. The mean nightly count of fish near RO 2 was 12.4 for control samples and 4.7 fish for test samples (Figure 5). The difference between control and test samples was statistically significant ($p = 0.009$, $n = 2$); (Table 2). Strobe lights reduced the number of fish near discharging RO 2 by 62%.

Fish densities near RO 2 were also highly variable between hourly samples of both control and test acoustic samples, but again fish densities were reduced when strobe lights were on compared to when turned off. Control samples had fish densities from zero up to 171 fish/ha, whereas test samples ranged from zero to seven fish/ha (Figure 6). The mean nightly density of fish near RO 2 was 31.0 fish/ha for control samples and 0.5 fish/ha for test samples. The difference between control and test samples was statistically significant ($p = 0.002$, $n = 2$); (Table 2). Strobe lights reduced the density of fish near discharging turbine three by 99%.

In addition, the distance from the strobe lights to the nearest fish varied largely between hourly samples, yet this distance was greater when the lights were on (Figure 7). The distance to the nearest fish in control samples ranged from 4.8 m to 58.0 m, whereas test samples ranged from 31.8 m to 112.9 m. The mean distance to the first fish was 3.7 times greater during control samples (65.1 m) than during test samples (17.5 m); (Table 2), which was highly significant (p <0.001, n = 2).

Table 2. Mean number of fish, fish density, and distance fish were deterred from strobe lights in a 60 m by 60 m area directly upstream of the opening of reservoir outlet 2 of Dworshak Dam, Idaho on four paired nights, April 24-27, 2006. All variables were measured with one set of nine strobe lights flashing at 360 flashes/min (test) and without the lights turned on (control).

		Mean Traces (number of fish)[a]			Mean Density (fish/ha)[a]			Mean Distance Deterred (m)[a]		
Sample Dates	**Replicate**	**Ctrl**	**Test**	**% Decrease**	**Ctrl**	**Test**	**% Decrease**	**Ctrl**	**Test**	**% Increase**
Apr 24-25	4	6.6	7.9	-18.9%	27.7	0.0	100.0%	21.2	55.1	260.2%
Apr 26-27	5	18.1	1.5	91.7%	34.4	0.9	97.3%	13.7	75.0	547.0%
	Mean	**12.4**	**4.7**	**62.1%, p = 0.009**	**31.0**	**0.5**	**98.5%, p = 0.002**	**17.5**	**65.1**	**372.0%, p < 0.001**

[a] Test of statistical significance performed using a “Mann-Whitney U-test.”

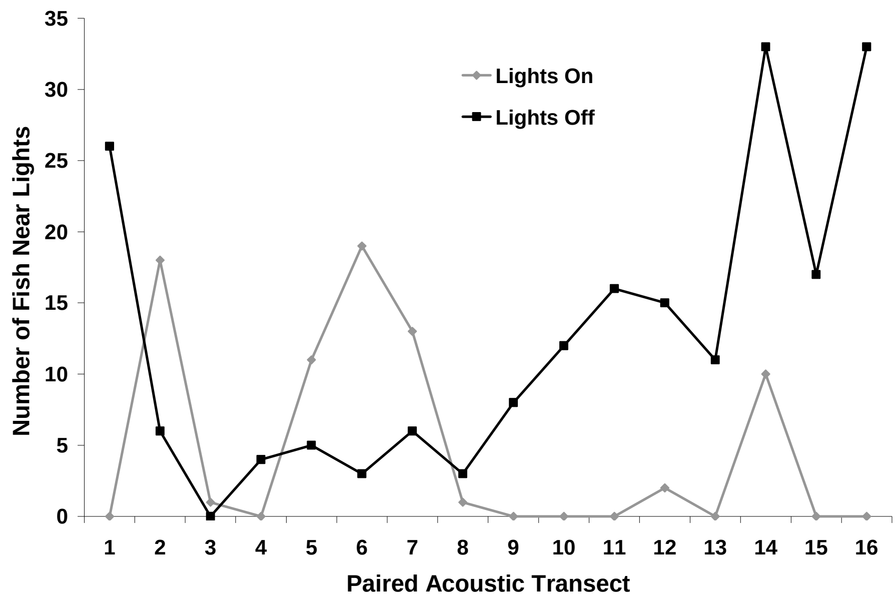

Figure 4. Number of fish in a 60 m by 60 m area directly upstream of reservoir outlet 2 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 2100 to 0500 hours. The x-axis represents five nights each of control and test conditions with at least nine transects per night. Each control/test pair was conducted on consecutive nights.

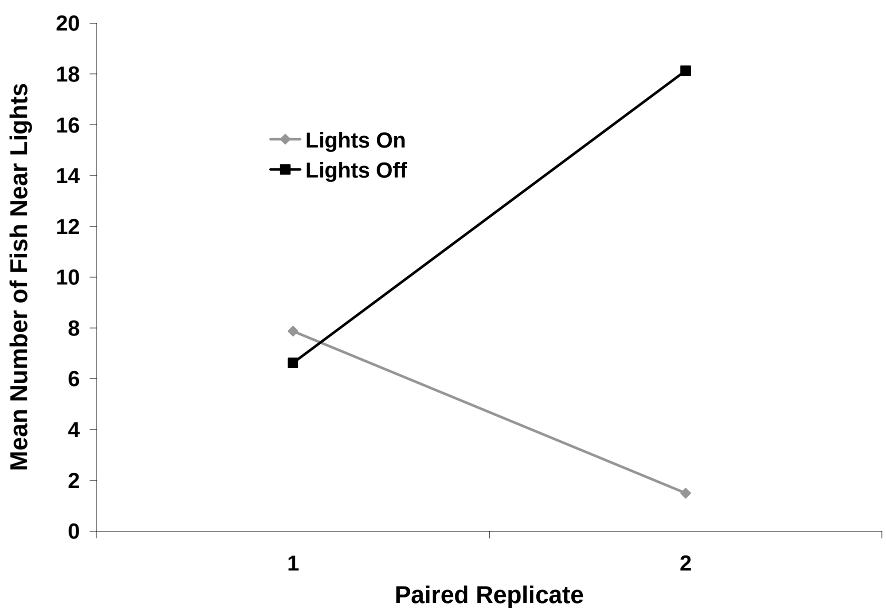

Figure 5. Mean number of fish in a 60 m by 60 m area directly upstream of reservoir outlet 2 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 2100 to 0500 hours. The x-axis represents the mean of all transects for each of five nights for either control or test conditions. Each control/test pair was conducted on consecutive nights.

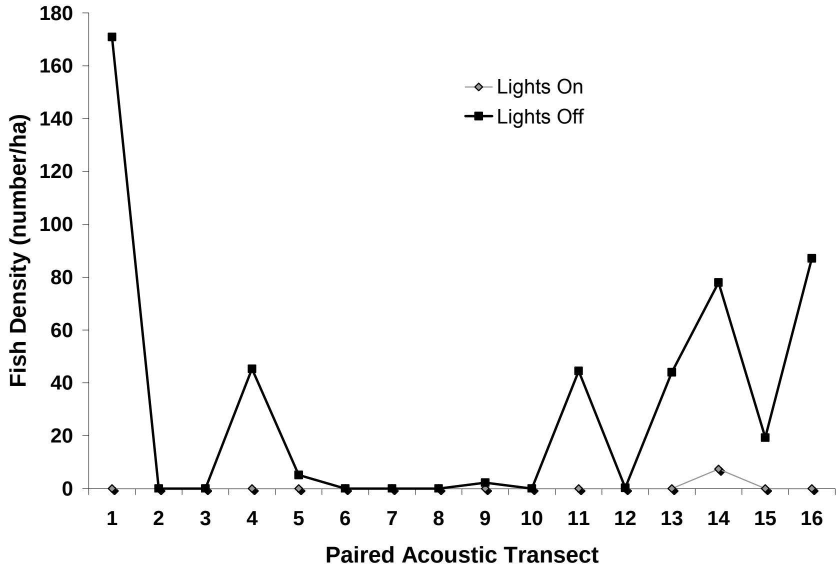

Figure 6. Fish density near reservoir outlet 2 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 2100 to 0500 hours. The x-axis represents two nights each of control and test conditions with eight transects per night. Each control/test pair was conducted on consecutive nights.

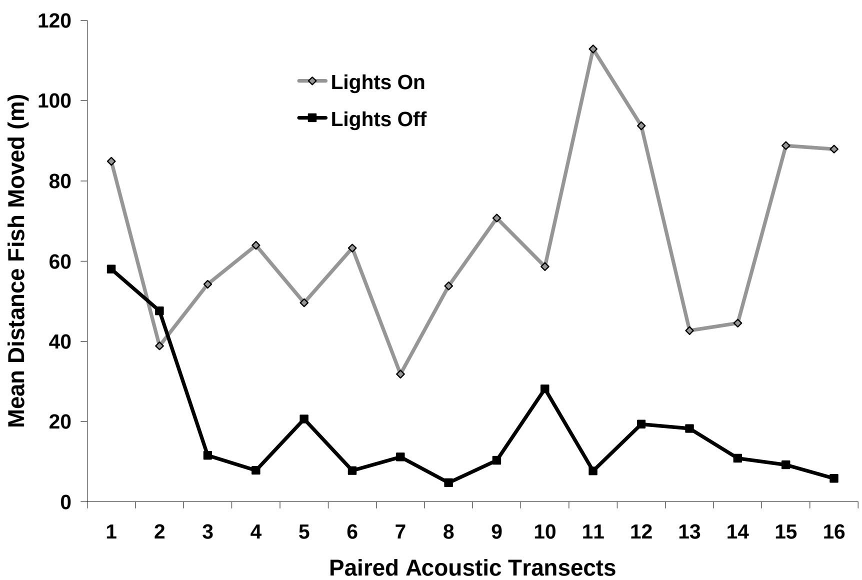

Figure 7. Mean distance fish moved from strobe lights near reservoir outlet 2 during control (lights off) and test (lights on) mobile hydroacoustic transects in Dworshak Reservoir, Idaho. Hourly transects were conducted at night from 2100 to 0500 hours. The x-axis represents two nights each of control and test conditions with eight transects per night. Each control/test pair was conducted on consecutive nights.

Kokanee Population Estimate

We estimated a total abundance of approximately 5,815,000 kokanee (90% CI +/- 27.6%) in Dworshak Reservoir on August 2006. This included 2,183,000 age-0 (90% CI +/- 24.2%), 1,509,000 age-1 (90% CI+/- 29.0%), and 2,124,000 age-2 (90% CI +/- 27.5%; Table 3).

The total density of all kokanee was estimated at 1,326 fish/ha, with 498 age-0/ha, 344 age-1/ha, and 484 age-2/ha (Figure 8). Total abundance (2,311,381) and density (4,436 fish/ha) were highest in section 3, followed by section 2 (2,079,000, 1,424 fish/ha) and lowest in section 1 (1,405,000, 584 fish/ha) (Figures 9 & 10). The abundance and density of each kokanee age class followed the same longitudinal gradient.

Table 3. Age class and total population estimates of kokanee in each of three sections of Dworshak Reservoir during August 1-3, 2006.

	Kokanee Abundance (x 1,000)			
Res. Section	**Total**	**Age 0**	**Age 1**	**Age 2**
1	1,444	549	300	595
2	2,060	825	588	647
3	2,311	810	621	881
Total (all sections)	**5,815**	**2,183**	**1,509**	**2,124**
90% C.I. (+/-)	1,607	527	437	584
%	27.6%	24.2%	29.0%	27.6%

Sixty-eight kokanee were sampled during creel surveys, with the largest measuring 225 mm (8.6 in) and smallest measuring 170 mm (6.7 in) (Figure 11). Angler caught kokanee were comprised of age-1 and age-2 fish; no age-3 kokanee were caught by anglers we sampled (Table 4; Figure 12). A total of 52 kokanee were captured during trawl sampling, with the largest measuring 211 mm (8.3 in) and smallest measuring 33 mm (1.3 in) (Figure 11). Trawl caught kokanee were comprised of all three ages (Table 4; Figure 12).

For the 2006 hydroacoustic population estimate, we defined age-0 kokanee as fish between –60.0 and –47.0 dB (0-80 mm). Age-1 kokanee were defined as fish between –46.9 and –40.0 dB (81-170 mm), and age-2 kokanee were defined as fish between –39.9 and –33.0 dB (171-413 mm) (Table 4; Figure 12). We placed confidence limits on the estimates for each age class.

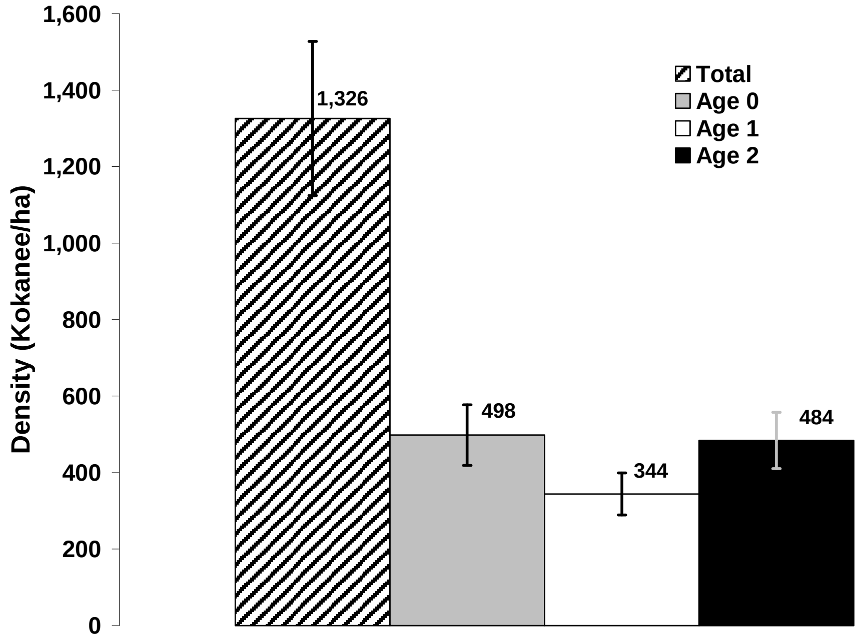

Figure 8. Density of age-0, age-1, age-2, and combined total density of kokanee in Dworshak Reservoir, August 1-3, 2006, obtained from hydroacoustics.

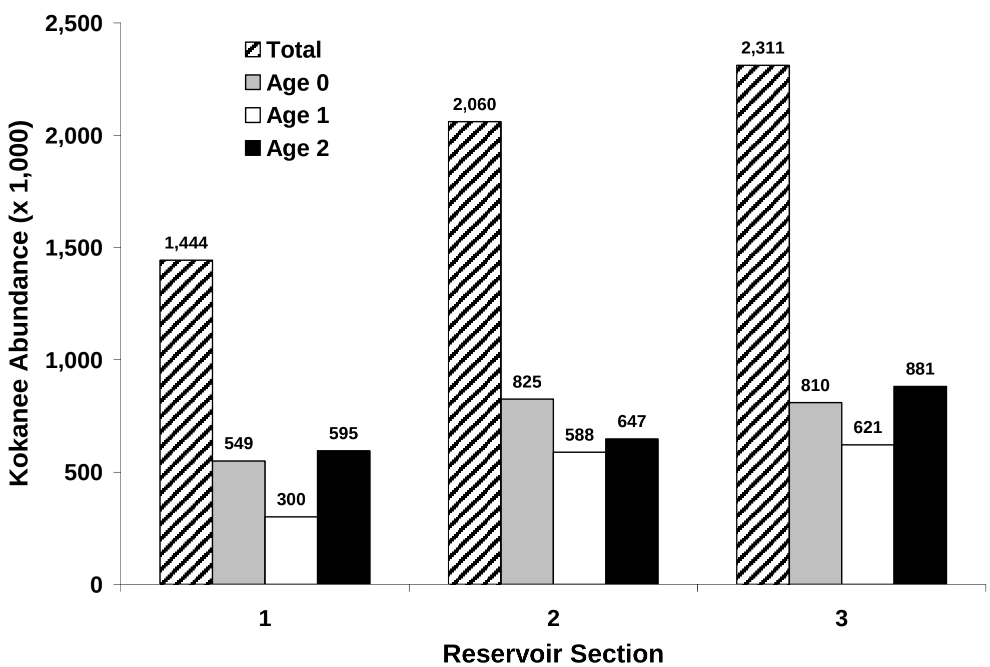

Figure 9. Abundance of age-0, age-1, age-2, and combined total abundance of kokanee by reservoir section in Dworshak Reservoir, August 1-3, 2006, obtained from hydroacoustics.

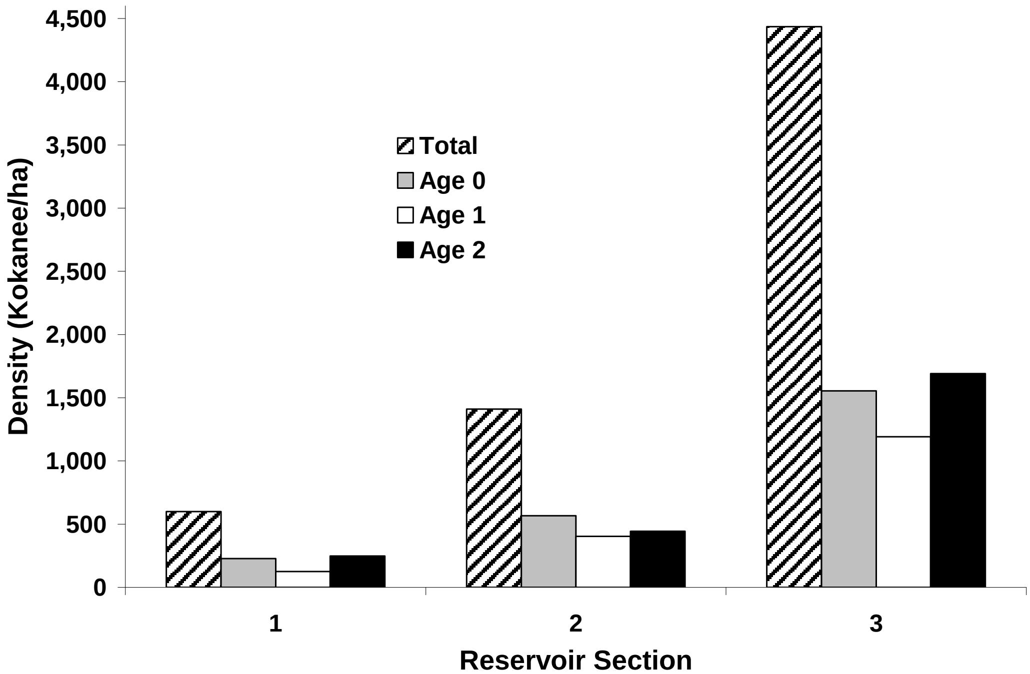

Figure 10. Density of age-0, age-1, age-2, and combined total density of kokanee by reservoir section in Dworshak Reservoir, August 1-3, 2006, obtained from hydroacoustics.

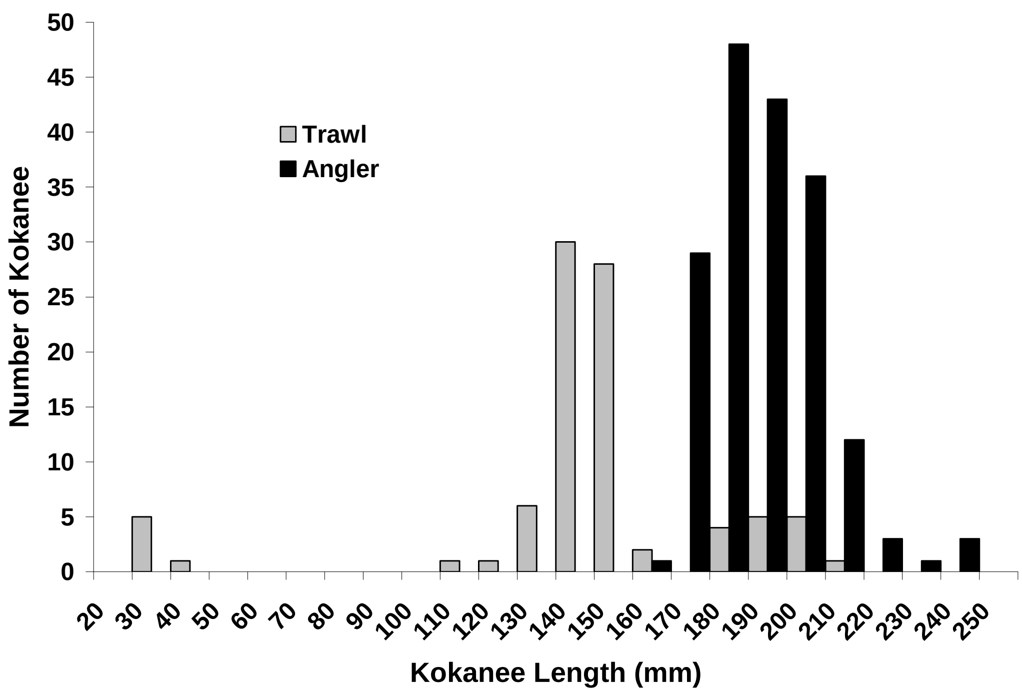

Figure 11. Length frequency of angler (June 20 and 28) and trawl (July 24) caught kokanee in Dworshak Reservoir, 2006.

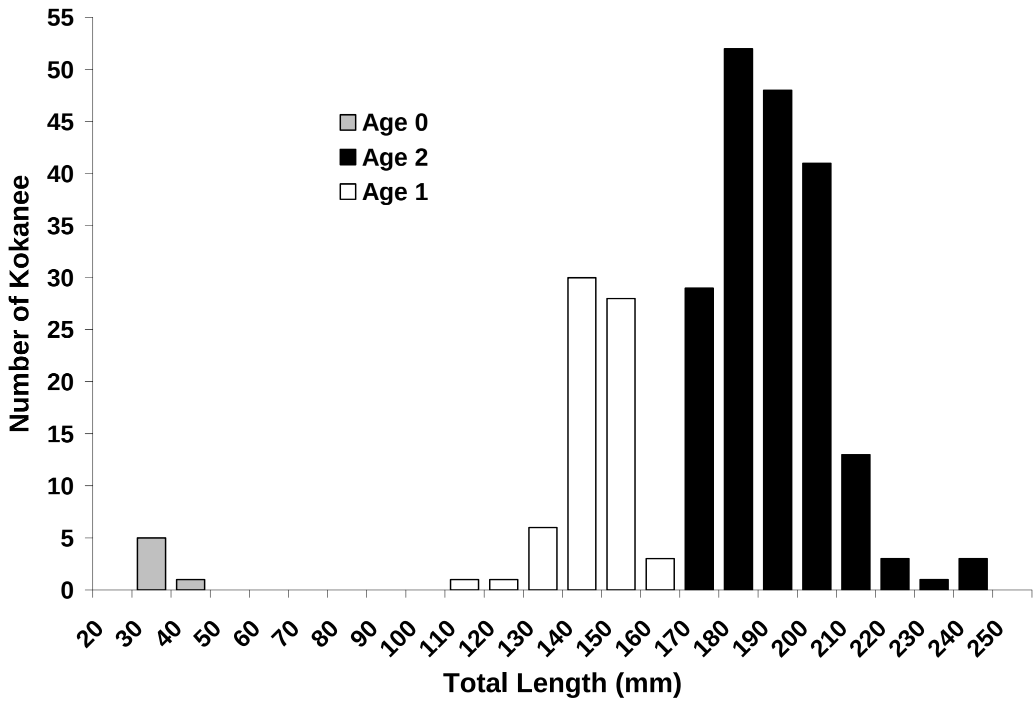

Figure 12. Age-at-length frequency of angler (June 20 and 28) and trawl (July 24) caught kokanee in Dworshak Reservoir, 2006.

Table 4. Age-0, age-1, and age-2 kokanee total length ranges and corresponding hydroacoustic target strengths.

Kokanee Total Length (mm)	Target Strength (-dB's)	Age (years)
0–80	-60.0 to -47.0	0+
90–170	-46.9 to -40.0	1+
171–413	-39.9 to -33.0	2+

Entrainment

Fish detection rates during entrainment sampling in 2006 were quite variable. The highest 24 h fish detection rate (19.5 fish/h) was found during two different sample periods: at turbine 3 on May 30 while discharging 150.1 m^3/s and at turbine 1 on June 5 while discharging 60.3 m^3/s (Table 5). Fish detection rates in general were high in front of all intakes during spring and early summer but then decreased dramatically in mid-summer and into early-fall 2006.

Table 5. Sampling conditions and fish detection rate in front of operating turbines of Dworshak Dam. Fish detections were made using fixed location hydroacoustics between May and September 2006. Detection rates were expanded by the percent coverage to estimate potential entrainment across the entire turbine opening.

Date	Turbine	Discharge (m^3/s)	Intake Depth (m)	Secchi Transparency (m)	Detection rate (fish/h)
5/16/2006	2	62.9	25.6	2.3	18.7
5/23/2006	1	60.6	15.2	2.1	19.0
5/30/2006	3	150.1	18.6	2.6	19.5
6/5/2006	1	60.3	17.4	2.6	19.5
6/6/2006	2	59.5	31.4	2.6	8.6
6/20/2006	2	42.5	23.2	3.5	16.9
7/5/2006	3	147.2	55.8	2.6	0.2
7/11/2006	RO 1	24.1	74.1	2.0	0.5
7/12/2006	RO 1	24.1	74.1	2.0	0.0
8/14/2006	2	62.9	39.8	3.7	1.5
8/15/2006	3	167.1	41.2	3.7	2.7
8/28/2006	1	58.0	34.6	2.7	2.9
9/18/2006	1	39.6	30.0	3.7	1.1

The highest mean fish detection rate among turbines was found in front of turbine 2 (12.0 fish/h) (Figure 13). Mean detection rate in front of turbine 1 was 10.3 fish/h, while the mean detection rate near turbine 3 was 8.1 fish/h. Differences between detection rates in front of turbines were not statistically significant in part due to high variances at each location (Figure 13). Fish detection rate was not correlated with either discharge (Figure 14) or Secchi water transparency (an index of water clarity) (Figure 15); however, a moderate positive relation with intake depth was observed (Figure 16).

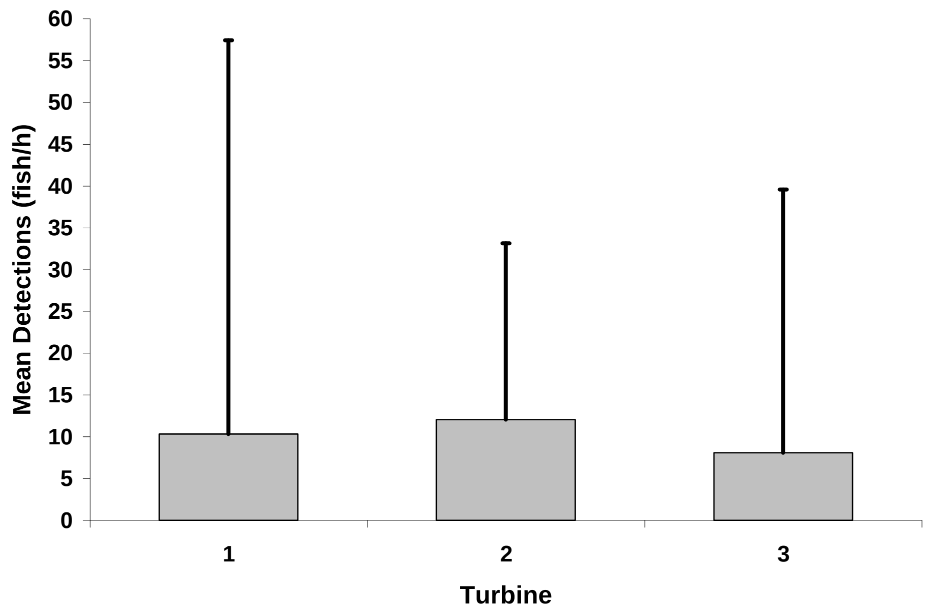

Figure 13. Mean fish detection rate in front of each of three turbines of Dworshak Dam, obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam. Vertical bar represents one standard deviation.

Fish were detected during all periods in front of the turbines. The highest mean detection rate was found during the dawn period (43.5 fish/h), followed by the night period (14.6 fish/h), and the dusk period (6.1 fish/h). We found only 2.3 fish/h during the day period, which was only 5% of the mean detection rate observed during dawn periods (Figure 17).

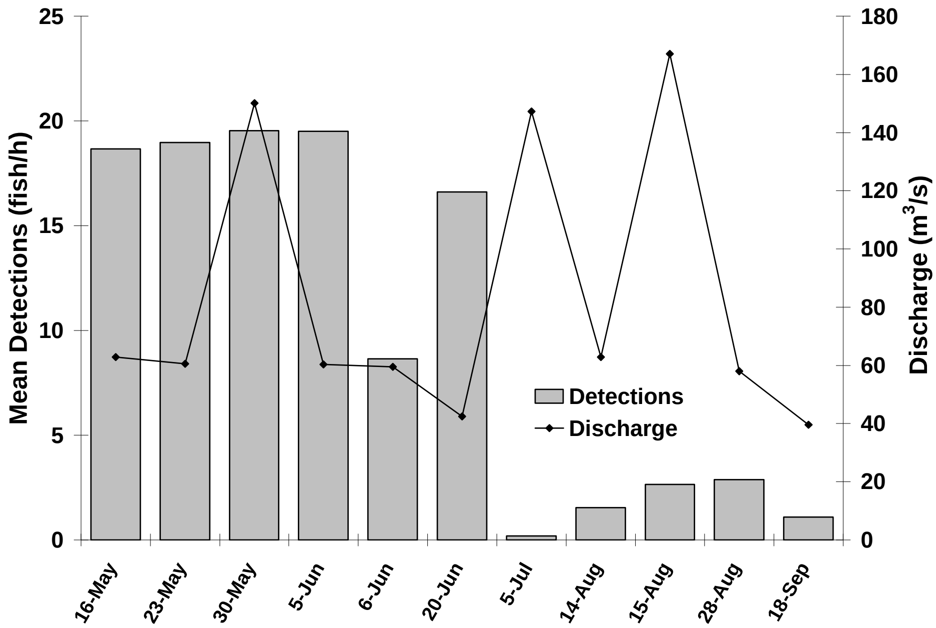

Figure 14. Mean fish detection rate in front of, and discharge rate of water through, the turbines of Dworshak Dam. Data were obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

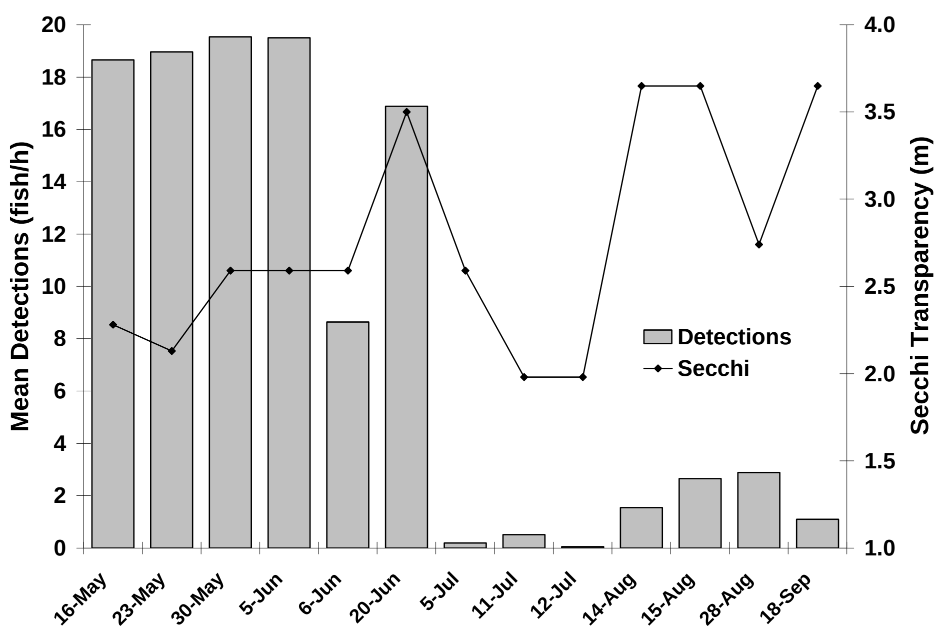

Figure 15. Mean fish detection rate in front of the turbines of Dworshak Dam and Secchi water transparency. Detection data were obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

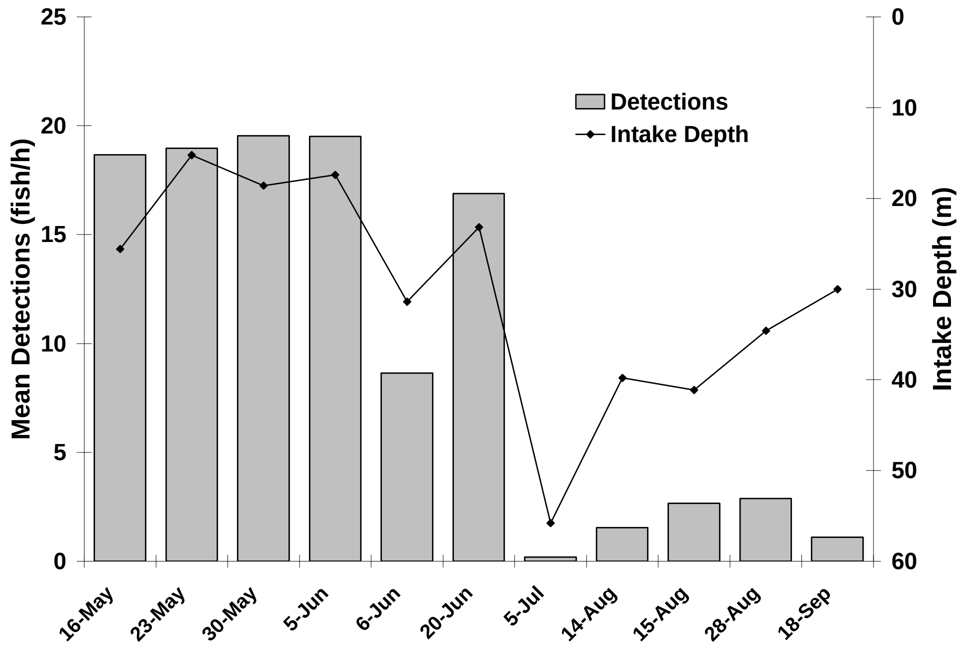

Figure 16. Mean fish detection rate and depth of water discharged through the turbines of Dworshak Dam. Data were obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

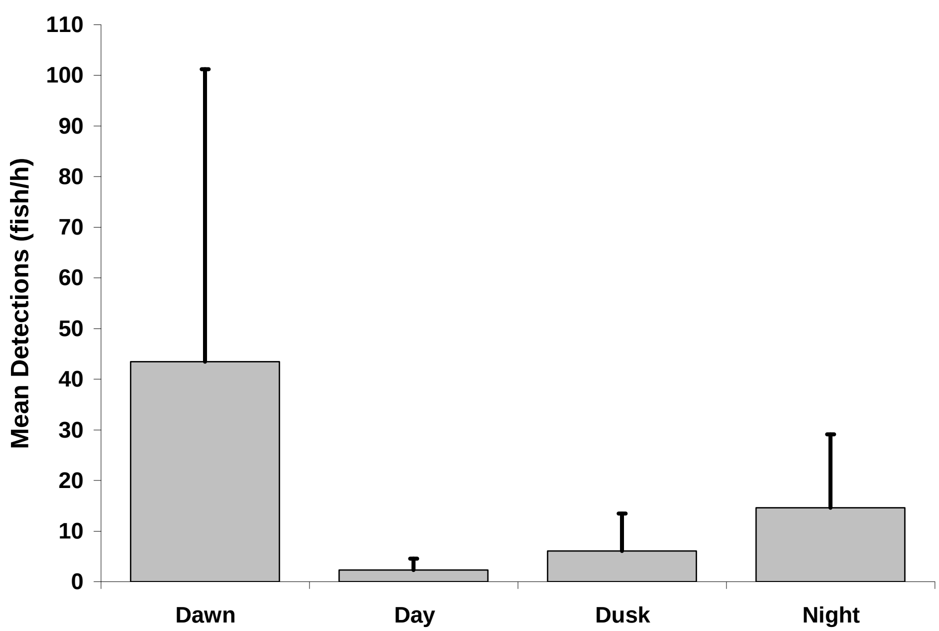

Figure 17. Mean fish detection rate in front of discharging turbines of Dworshak Dam, for each of four time of day strata (dawn, day, dusk, and night). Data were obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam. Vertical bars represent one standard deviation of the mean detection rates.

Discharge

During this contract, mean monthly discharge from Dworshak Dam ranged from a low of 37.1 m^3/s in November to a high of 291.1 m^3/s during April 2006 (Figure 18). Pool elevation varied with the amount of water discharged according to the USACE operational schedule (USACE, 1986). Pool elevation varied from a low pool of 462.5 m in early November to a full pool of 487.4 m from June 27 though July 4, 2006 (Figure 19). Water releases during summer months ('Salmon Flows') continued in 2006 and lasted from July 5 through September 13. These high discharge releases were intended to aid smolt migration and cool water temperatures in the Lower Snake River. Total discharge through Dworshak Dam was at or very near minimum discharge (39.6 m^3/s) for a total of 80 days. Secchi water transparencies generally decreased with greater discharge rates (Figure 20). Secchi transparency was lowest during mid-July and highest in late-October.

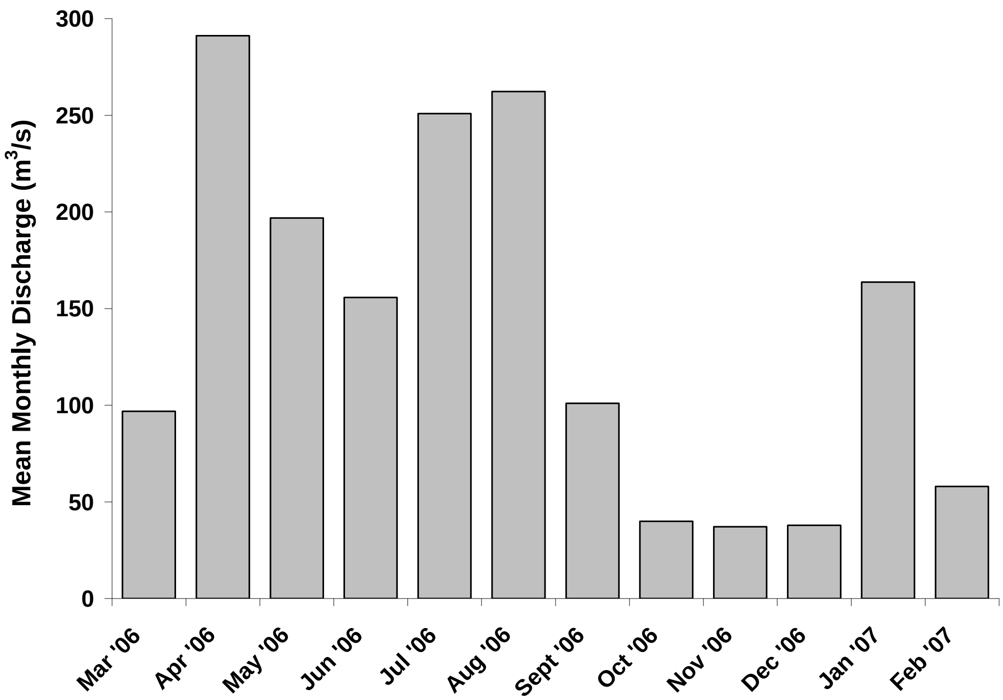

Figure 18. Mean monthly discharge through Dworshak Dam, March 2006—February 2007.

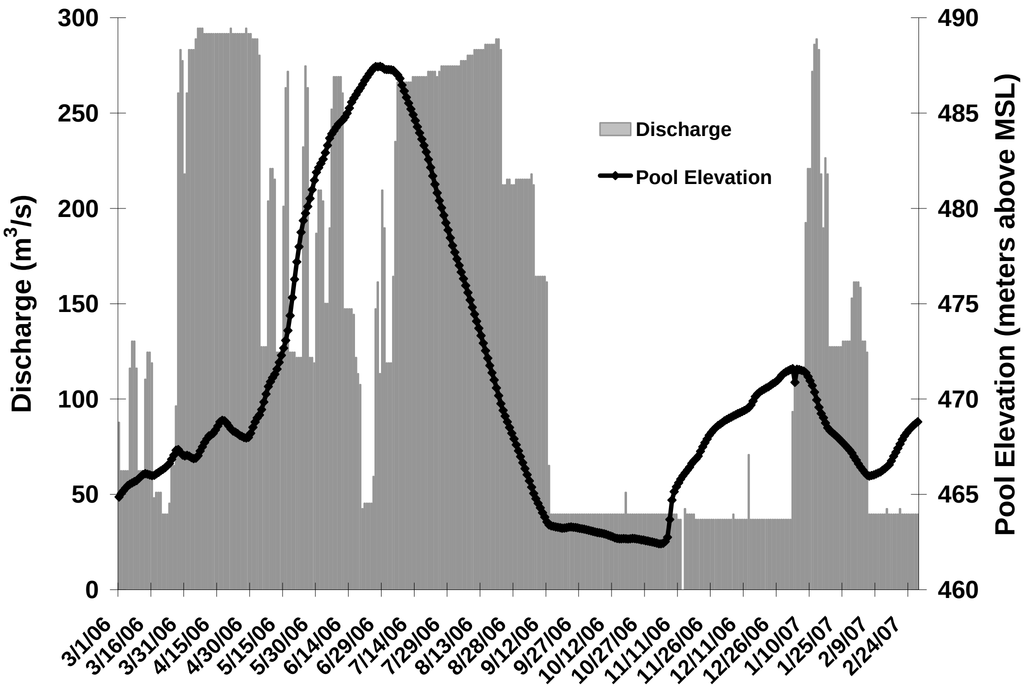

Figure 19. Total discharge through Dworshak Dam and Dworshak Reservoir pool elevation, March 2006–February 2007.

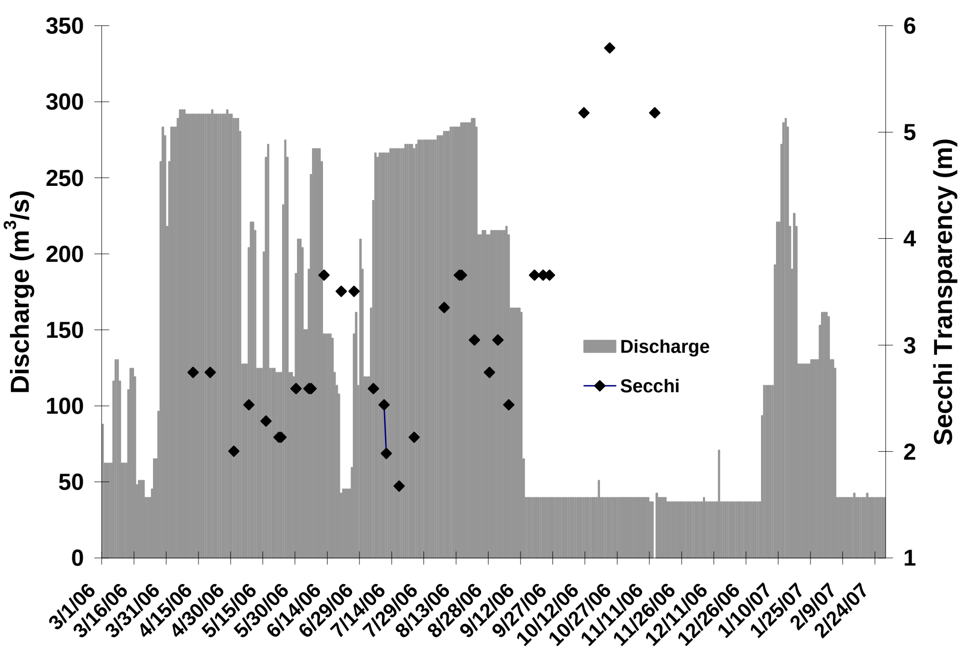

Figure 20. Total discharge through Dworshak Dam and Secchi water transparency, March 2006–February 2007.

Spawner Counts

We counted 29,743 spawning kokanee in four index streams (Table 5). This was more than twice the number of kokanee counted in spawning tributaries in 2005 (13,359). A subsample of 75 spawners was collected from Isabella Creek during the counts. Fish ranged from 180 to 250 mm in length, with a mean of 210 mm (Figure 21).

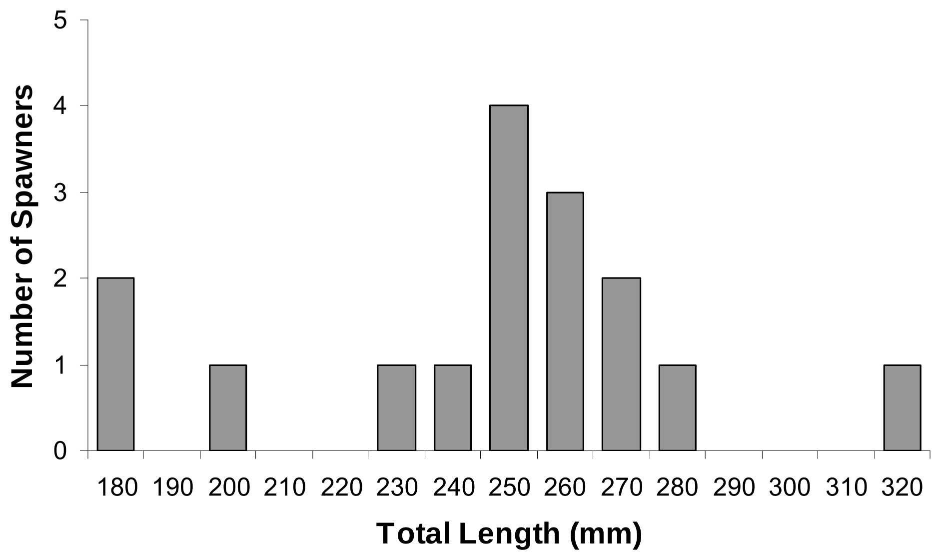

Figure 21. Length frequency distribution from a subsample of 75 kokanee spawners from Isabella Creek, September 28, 2006.

Table 6. Number of kokanee spawners counted in selected tributaries to Dworshak Reservoir, Idaho during September 1987-2006.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total
2006	12,604	12,077	2,717	2,345	29,743
2005	6,890	3,715	2,137	617	13,359
2004	6,922	2,094	450	1,474	10,940
2003	12,091	10,225	1,296	1,083	24,695
2002	15,933	7,065	2,016	1,367	26,381
2001	3,751	1,305	722	301	6,079
2000	3,939	402	124	565	5,030
1999	10,132	361	827	2,207	13,527
1998	627	20	13	18	678
1997	144	0	0	0	144
1996	2,552	4	13	82	2,651
1995	12,850		2,780	1,160	16,790
1994	14,613	12,310	4,501	1,878	33,302
1993	29,171	7,574	2,476	6,780	46,001
1992	7,085	4,299	1,808	1,120	14,312
1991	4,053	1,249	693	590	6,585
1990	10,535	3,219	1,702	1,875	17,331
1989	11,830	5,185	2,970	1,720	21,705
1988	10,960	5,780	5,080	1,720	23,540
1987	3,520	1,351	1,477	700	7,048

DISCUSSION

Strobe Light Testing

We observed a 62% reduction in fish abundance and a 98% reduction in densities near RO 2 at low discharge while strobe lights were in use. The reduction in density was much greater than previous tests in front of RO 2 at low discharge during April and May 2002 (66%; Stark and Maiolie 2004).

One limitation of this work was that we only monitored the response of fish over -45 dB, which would be a kokanee of about 97 mm total length (Love 1971). Fish below this size were difficult to separate from the ambient noise near the dam and reservoir outlets. Another issue that was previously suspected as a confounding factor was the idea that fish might become habituated to the flashing lights over time (Stark 2006). However, we did not see any evidence of habituation during these tests. Additionally, previous offsite testing on Lake Pend Oreille and Spirit Lake did not find evidence of fish habituation (Maiolie et al. 2001).

All of this testing was conducted at night. Effectiveness of strobe lights during the daytime has not been evaluated but is likely to be reduced due to the high levels of background lighting. In addition, through entrainment monitoring we found most losses occurred during the night. Thus, nighttime use of underwater strobe lights should provide sufficient deterrence of fish away from Dworshak Dam to effectively reduce entrainment on a population level.

The magnitude of reduction in abundance (62%) and density (99%) observed during strobe light testing in front of an RO 2 may be large enough to meet our objective of reducing fish entrainment by 50%. However, to date, testing has been quantified only through abundance and density measures. Thus, in future testing we recommend obtaining true measures of fish entrainment with newly installed hydroacoustic transducers inside the turbine units. Comparison of control (lights off) versus test (lights on) entrainment rates (fish/h) will be a more definitive test of strobe light effectiveness.

Table 7. Mean number of fish, fish density, and distance fish were deterred from strobe lights directly upstream of the opening of reservoir outlet 2 of Dworshak Dam, Idaho on six paired nights April 22-23, May 8-9, and May 13-14, 2002 and four paired nights, April 24-27, 2006. All variables were measured with one set of nine strobe lights flashing at 360 flashes/min (test) and without the lights turned on (control).

		Mean Traces (number of fish)[a]			Mean Density (fish/ha)[a]			Mean Distance Deterred (m)[b]		
Sample Dates	**Replicate**	**Ctrl**	**Test**	**% Decrease**	**Ctrl**	**Test**	**% Decrease**	**Ctrl**	**Test**	**% Increase**
Apr 22-23, 2002	1	6.4	9.2	-43.1%	109.6	95.6	12.78%	15.1	46.2	306.1%
May 8-9, 2002	2	8.1	2.9	64.4%	228.4	70.6	69.11%	7.8	36.0	459.0%
May 13-14, 2002	3	12.1	4.1	66.1%	420.7	95.1	77.39%	3.3	37.6	1131.9%
Apr 24-25, 2006	4	6.6	7.9	-18.9%	27.7	0.0	100.0%	21.2	55.1	260.2%
Apr 26-27, 2006	5	18.1	1.5	91.7%	34.4	0.9	97.3%	13.7	75.0	547.0%
	Mean	**10.3**	**5.1**	**50.5%, p=0.214**	**164.2**	**52.4**	**68.1%, p=0.134**	**12.2**	**50.0**	**409.8%, p=0.003**

[a] Test of statistical significance performed using a "'Paired T-test."
[b] Test of statistical significance performed using a "Mann-Whitney U-test."

Effectiveness testing of strobe lights proceeded in phases from offsite testing to increasingly greater discharge rates and number of turbines in onsite testing at Dworshak Dam. Offsite testing on Lake Pend Oreille and Spirit Lake proved strobe lights were highly effective in repelling kokanee (Maiolie et al. 2001). The next phase progressed to testing in front of a single operating turbine on Dworshak Reservoir. Again, these tests demonstrated the lights reduced kokanee densities by 88% (Stark and Maiolie 2004). Onsite testing was needed to see if kokanee could be repelled even when there were water currents that could influence fish behavior and when kokanee could be actively attempting to move downstream (conditions that were not present in the offsite testing). These onsite tests demonstrated success in spite of these factors.

Strobe lights have now proved successful in front a single discharging turbine, two simultaneously discharging turbines, single turbine at high discharge, and in front of discharging ROs at Dworshak Dam (Stark and Maiolie 2004). The next phase is to implement one of two designs already developed to permanently install this behavioral deterrent technology on Dworshak Dam (Stark 2006).

Kokanee Population Estimate

Population estimates indicated total kokanee abundance increased from 3.0 million in 2005 to 5.8 million in 2006. The abundance of each age class of kokanee also increased in 2006. And, adult (age-2) density increased from 21 adults/ha in 2004 to 484 adults/ha in 2006 (Table 8). Despite their increased abundance, age-1 kokanee did not recruit to the fishery (based on limited creel surveys) because of their small size.

Age-1 to age- 2 annual survival was calculated at 71% (Figure 22) between 2005 and 2006. We would have expected 60% annual survival rates for a population with little or no predation (Maiolie and Elam 1995), so this estimated survival rate is higher than expected. However, we must caution that this survival rate is based upon 2005 abundances estimated with BioSonics hydroacoustic gear, which we have evidence to suggest likely underestimates densities. Nonetheless, true survival is likely still high.

Abundance of age-0 kokanee in 2006 was high, which suggested good adult spawning success in 2005 and subsequent fry survival. However, high abundance and density of not only fry, but all age classes negatively influenced growth. This is evidenced by decreased average total length for all age classes compared to previous years. The average size of age-2 kokanee was smaller in 2006 (205 mm, 8.1 in) than in 2005 (257 mm, 10.1 in). In summary, record densities of kokanee in 2006 appear to have caused the most extreme density-dependent growth ever documented in Dworshak Reservoir.

Table 8. Estimated age class abundance and adult densities of kokanee in Dworshak Reservoir, Idaho, by hydroacoustic and trawl sampling, 1988-2006.

Year	Sampling Method	Kokanee Abundance					Adult Density (fish/ha)
		Age 0	Age 1	Age 2	Age 3	Total	
2006	Hydroacoustic	2,182,983	1,508,780	2,123,632	0	5,815,395	484
2005	Hydroacoustic	2,134,986	769,663	107,466	0	3,011,626	21
2004	Trawling	2,136,892	692,348	90,715	0	3,919,956	14
2003	Hydroacoustic	439,580	434,586	276,055	0	1,150,222	42
2002	Hydroacoustic	1,246,959	1,101,232	127,933	0	2,476,124	24
2001	Hydroacoustic	1,962,000	781,000	405,000	0	3,150,000	75
2000	Hydroacoustic	1,894,857	303,680	199,155	0	2,397,691	37
1999	Hydroacoustic	1,143,634	363,250	38,464	0	1,545,347	7
1998	Hydroacoustic	537,000	73,000	39,000	0	649,000	7
1997	Trawling	65,000	0	0	0	65,000	0
1996	Hydroacoustic	231,000	43,000	29,000	0	303,000	5
1995	Hydroacoustic	1,630,000	1,300,000	595,000	0	3,539,000	110
1994	Hydroacoustic	156,000	984,000	304,000	9,000	1,457,000	69
1993	Trawling	453,000	556,000	148,000	6,000	1,163,000	33
1992	Trawling	1,040,000	254,000	98,000	0	1,043,000	22
1991	Trawling	132,000	208,000	19,000	6,000	365,000	5
1990	Trawling	978,000	161,000	11,000	3,000	1,153,000	3
1989	Trawling	148,000	148,000	175,000	0	471,000	32
1988	Trawling	553,000	501,000	144,000	12,000	1,210,000	29

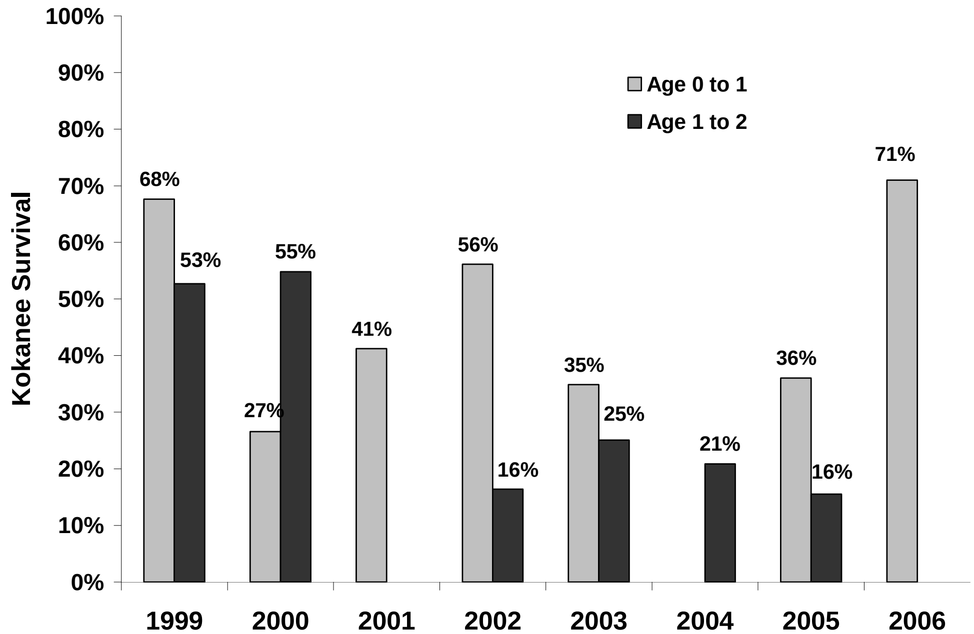

Figure 22. Percent survival of kokanee in Dworshak Reservoir from age-0 to age-1 and age-1 to 2, 1999-2006. Survival rates were estimated from age class abundances from annual hydroacoustic surveys (1999-2003, and 2005-2006) and a trawl survey in 2004.

Entrainment

Fish detection rates from entrainment assessment sampling remained highly variable with a few different findings than previous years (2002-2005) while several other patterns continued during 2006. Mean fish detection rates were highest during spring, concurrent with the high discharge period from April through June 2006 (Table 9). This matches previous findings, with the exception of 2005.

However, several different patterns in fish detections were observed during 2006 than in previous entrainment assessments. Unlike previous results (2002-2005), in 2006 we found the highest detection rate during the dawn period (43.5 fish/h) not the night period, although the night was the next highest period (14.6 fish/h) (Figure 17). We also found low fish detection rates throughout July and August sampling during high discharge periods similar to findings in 2005, but unlike previous assessments (Figure 14).

Maiolie and Elam (1998) documented movements of kokanee throughout the reservoir. They also found that kokanee densities near the dam were low during the August drawdowns largely because kokanee (mostly age-2 fish) were further up the reservoir. Thus, seasonal fish distribution and density of kokanee near the dam likely influenced entrainment potential, along with the influence of discharge rate.

Similar to findings in 2002 and 2003, we detected more fish in front of turbine 2 than turbine 1, and more in front of turbine 1 than turbine 3 (Figure 13). However, turbine 3 was typically only operated during periods of high discharge in the spring and mid-summer, as was turbine 2, although to a lesser extent. Turbine 1 was operated almost year-round and mostly at or near minimum discharge rates. Thus, entrainment potential was not mutually exclusive of discharge rate through each turbine (Figure 23). In addition, comparisons between turbines were also likely influenced by the time of the year (season) turbines were operated. For instance, turbine units 1 and 2 were more likely to be discharging during the spring. Lastly, the variation in the number of detections for each turbine was greater than the difference in detection rate between them; thus, their differences were not statistically significant.

Unlike 2004 and 2005, we found a strong negative relationship between depth of intake and fish detection rate (Figures 16 and 24). But, withdrawal depth again was not independent of discharge rate, season, or intake unit. However, the sample periods with the highest detection rates all occurred while the depth of water withdrawal was about 30 m, which happens to be the typical depth of kokanee during the night (Maiolie and Elam 1998). Lastly, we did not find a relationship between detection rate (kokanee entrainment susceptibility) and Secchi transparency (water clarity). Again, water clarity was not independent of season and discharge rate.

The percent of the turbine opening covered by our hydroacoustic sampling was highly variable (Table 9). Changes in depth of discharge through dam intakes, as affected by pool elevation and selector gate operation, changed our sampling efficiency. The fixed-site hydroacoustic transducer used for fish detection immediately in front of turbine intake openings had side lobes that detect the face of the dam. This detection resulted in severe noise intrusion into entrainment assessment echograms, especially within the 15-30 m depth range. More efficient coverage of the intakes was obtainable when the reservoir was closer to full pool since the intake depths were deeper, below the side-lobe noise band. Relatively noise free entrainment sampling was attainable when the intakes were quite shallow (<15 m deep), yet the acoustic coverage was drastically reduced since the acoustic beam was narrow near the surface.

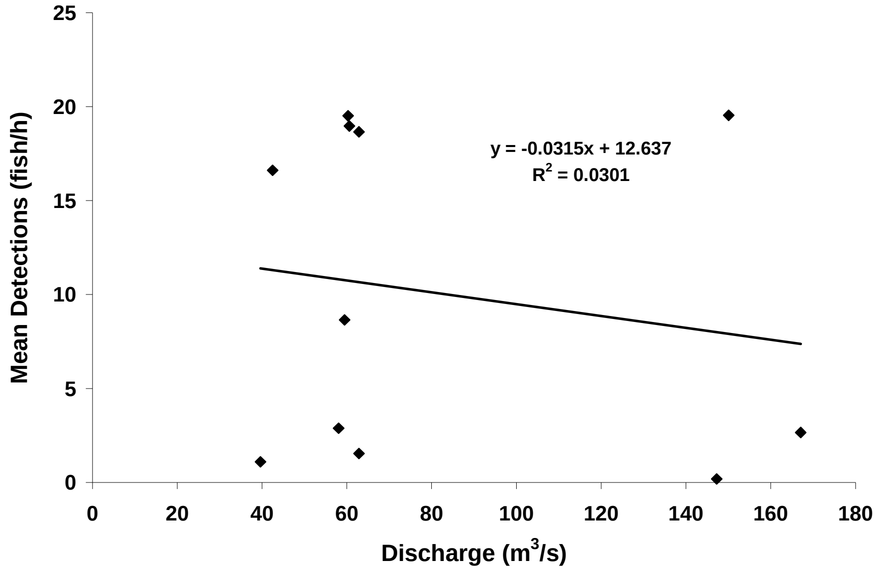

Figure 23. Relationship between fish detection rate and discharge rate of water through the turbines of Dworshak Dam obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

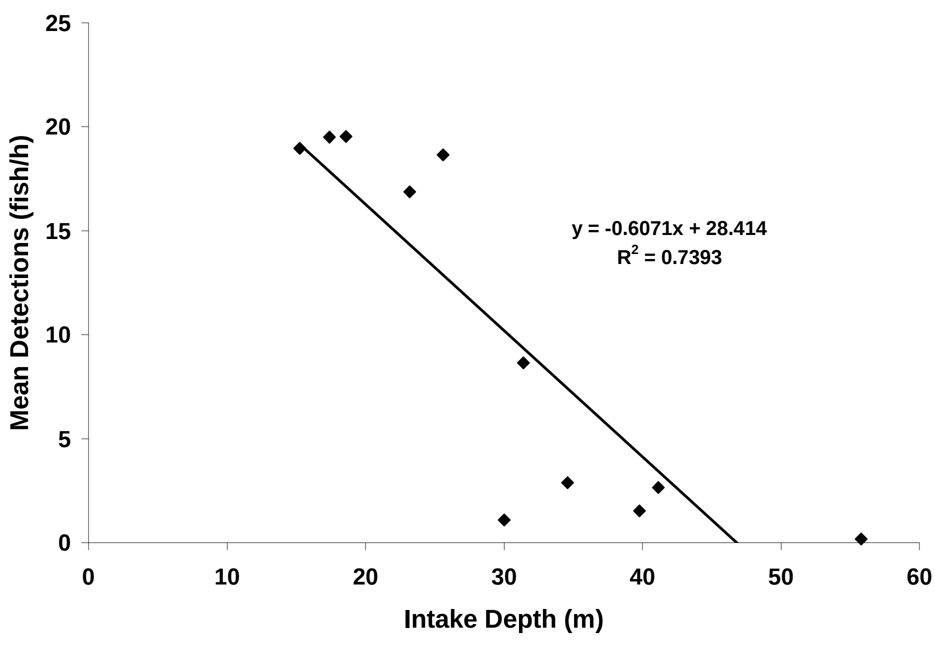

Figure 24. Relationship between fish detection rate and intake depth of water discharged through the turbines of Dworshak Dam obtained from 24 h fixed-site hydroacoustic sampling, May—September 2006. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

Table 9. Conditions, settings, acoustic beam coverage, and proximities to the turbine units of Dworshak Dam during entrainment sampling, May–September 2006. Beam diameter, portion of intake sampled, and distance from beam to dam were values at the center of the openings.

Date	Turbine	Intake Width (m)	Offset Angle (deg°)	Analysis Depths (m)	Beam Diameter (m)	Acoustic Beam Coverage (%)	Distance from beam edge to Dam (m)
5/16/2006	2	3.7	7.5	20.6-30.6	3.0	80.7%	2.9
5/23/2006	1	3.7	7.0	10.2-20.2	1.8	48.0%	1.2
5/30/2006	3	6.1	6.5	13.0-23.0	2.1	35.2%	1.3
6/5/2006	1	3.7	7.0	12.4-22.4	2.0	54.8%	1.4
6/6/2006	2	3.7	7.5	26.4-36.4	3.6	99.0%	3.4
6/20/2006	2	3.7	6.0	18.2-28.2	2.7	73.0%	2.3
7/5/2006	3	6.1	5.0	49.0-62.0	6.4	105.5%	3.1
8/14/2006	2	3.7	6.0	30.0-49.0	4.6	125.4%	3.2
8/15/2006	3	6.1	6.0	30.0-53.0	4.7	77.8%	3.4
8/28/2006	1	3.7	6.0	25.5-43.7	4.0	109.1%	2.9
9/18/2006	1	3.7	7.5	25.9-34.1	3.5	94.6%	3.3

An increase in sampling effort would allow us to obtain enough hours of fish detections (sample size) to allow for statistically valid tests of the effects of time of day, seasons, discharge rate, and depth of withdrawal. Sample sizes must be large enough to statistically test for the effects of one factor while controlling for the remaining factors.

Lastly, transducers installed inside the turbine intake monoliths (inside and downstream of the selector gates and trash racks) may be the best option to monitor entrainment since fish detected in this area have a much higher probability of being pulled into the turbine penstocks.

Discharge

The 2006 water year was average to slightly above average when compared to 1999 though 2005 water years (Figure 25), with a mean annual discharge through Dworshak Dam of 159 m^3/s. The high discharge period was longer in duration than in 2005 and peaked at a slightly higher mean total discharge (Figure 26), very similar to the 2003 water year. The opportunity for entrainment losses was greater during the spring of 2006 compared to 2005, but still lower relative to previous years (1999-2004). Yet, higher discharges in 2006 did not appear to negatively impact the kokanee population based upon hydroacoustic population estimates.

Discharge of water through Dworshak Dam during 2006 did not appear to have adversely impacted kokanee abundance, since age-2 kokanee abundance and density were at record highs. Furthermore, entrainment assessments during July and August revealed high discharge “Salmon Flows” were not likely impacting kokanee abundance severely. Very few fish were detected (Figure 14) during July and August entrainment assessments because most kokanee were distributed in the upper reservoir. Yet, fish detection rates were quite high during high discharges earlier in the spring. Our 2006 results were similar to findings during 2002-2003, which indicated the majority of fish losses likely occurred during high discharge periods primarily during the spring. In contrast, results from 2005 sampling showed high detection rates during the low discharge periods in the late summer and fall.

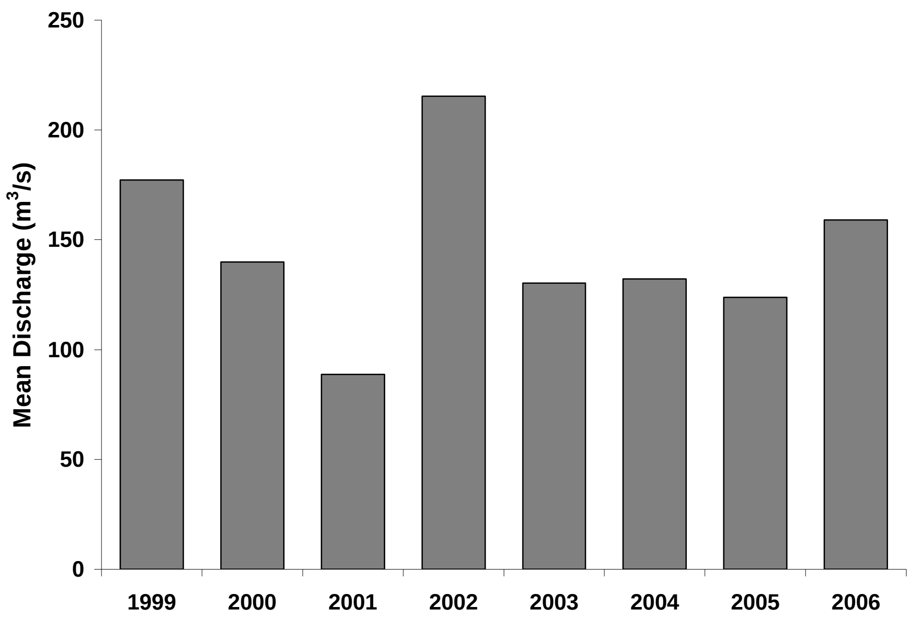

Figure 25. Mean annual discharge through Dworshak Dam, 1999-2006.

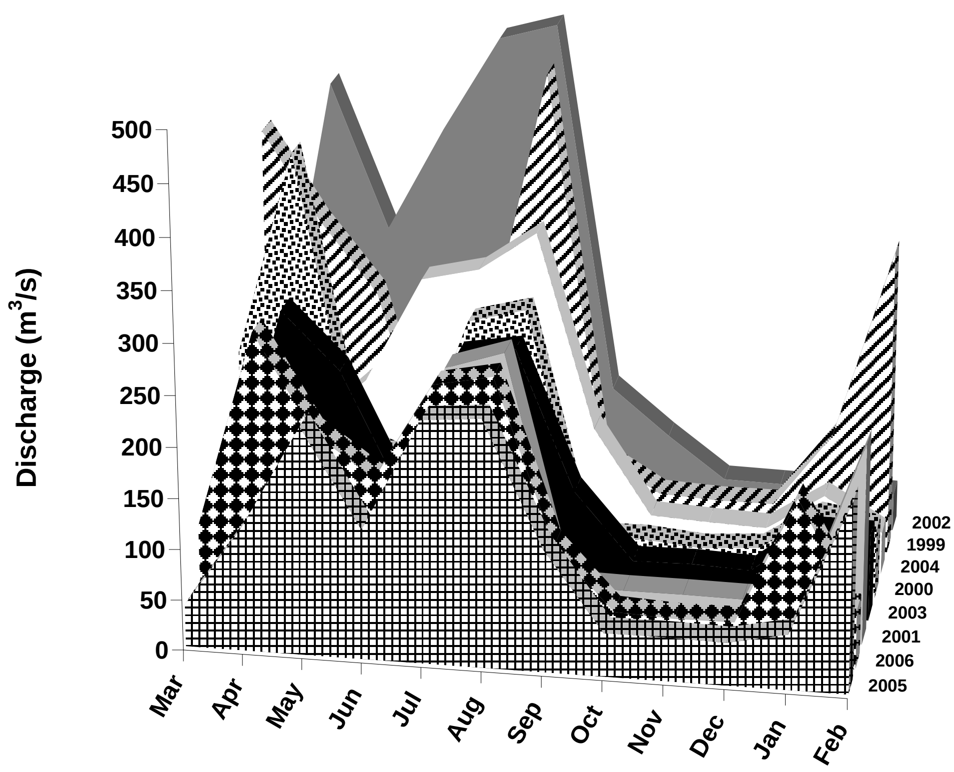

Figure 26. Mean monthly discharge through Dworshak Dam, 1999-2006.

Spawner Counts

Counts of spawning kokanee in 2006 were more than double 2005 counts (Table 6). The abundance of spawning fish coincided with what we expected for the index tributaries based upon the largest ever observed kokanee abundanceseen in the 2005 acoustic population estimate (Table 3). This year's data stretches the previous established relationship between spawner counts and reservoir adult abundance (Figure 28), since these values are at or near the largest numbers recorded from Dworshak.

Kokanee were able to access most of the prime spawning gravel during this year's survey because of moderate water levels. The previous barrier to upstream movement in Quartz Creek at river mile 0.8 appeared to have been obliterated since 2003. Spawning fish migrated upstream as far as RK 4.8 and 2.1 on Isabella and Skull creeks, respectively, but no migration barriers were evident at these locations.

The variability in total length of adults was much lower in 2006, with fish ranging from 180 to 240 mm TL, compared to 180 to 320 mm TL in 2005. The mean spawner length was 210 mm in 2006, compared to 248 mm TL in 2005. This decrease in mean size of spawning kokanee is not surprising since extremely high densities of kokanee in 2006 likely slowed growth and resulted in smaller adults.

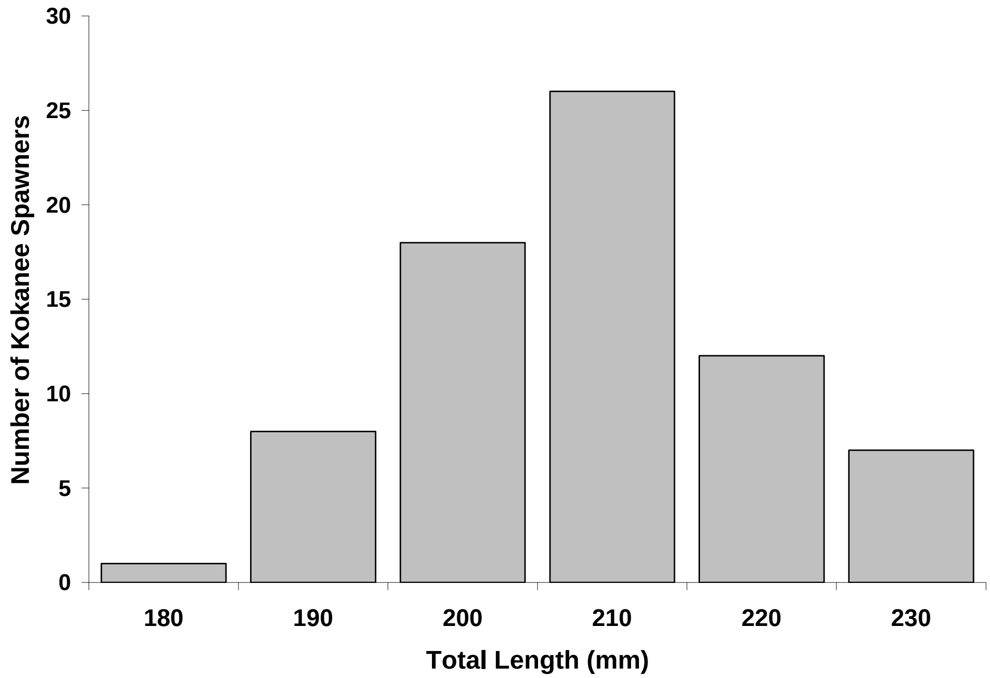

Figure 27. Length frequency distribution from a subsample of kokanee spawners from Isabella Creek, September 24, 2006. Mean total length was 210 mm.

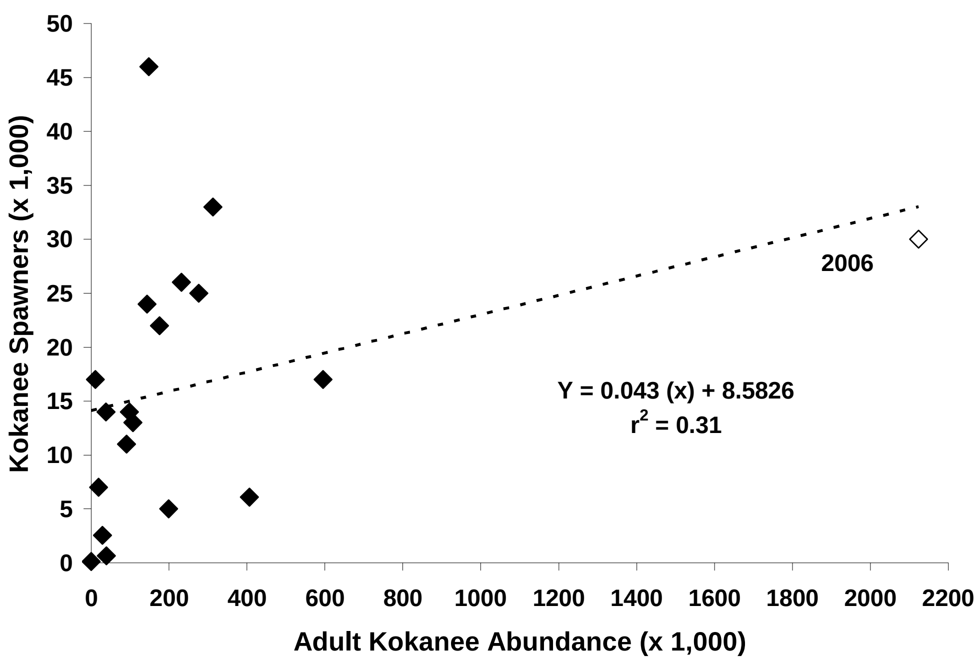

Figure 28. Relationship between adult kokanee abundance in Dworshak Reservoir and kokanee spawner abundance in tributaries to the North Fork Clearwater River, 1981—2006. The dotted trend line represents the linear regression equation for the relationship between adult and spawner abundances. The white diamond represents 2006 values.

CONCLUSIONS

Underwater strobe light tests in front of RO 2 were highly effective at repelling kokanee away from Dworshak Dam. Declines in fish counts (62.1%, $p = 0.009$) and densities (98.5%, $p = 0.002$) were both statistically significant. The magnitude of reduction in abundance and density may be large enough to meet our objective of reducing fish entrainment by 50% and sufficient to keep populations within the management goal on an annual basis.

Dworshak Reservoir kokanee abundance increased dramatically from 2005 and was the highest abundance and density on record. However, densities of harvestable-size kokanee were above Dworshak Reservoir management goals, which resulted in lower catch rates of smaller kokanee. Mean monthly discharge in 2006 was slightly above the average for the last six years. Despite this discharge of water through Dworshak Dam during 2006, it did not appear to have adversely impacted kokanee abundance, since age-2 kokanee abundance and density were at record highs.

The highest fish detection rates from entrainment assessments were found during dusk periods and lowest during the day. Similar to previous assessments, fish detection rates were high during high discharges in the spring but low during high discharge “Salmon Flows” in July and August. Although “Salmon Flows” were not likely impacting kokanee abundance, this could be attributed to how kokanee are distributed during this time, mostly in the upper reservoir.

RECOMMENDATIONS

1. We recommend using strobe lights at night near operating reservoir outlets whenever kokanee densities in the forebay are high (Stark and Maiolie 2004) to lessen entrainment losses. This will help maintain adult kokanee densities between 30 to 50 fish/ha and improve the fishery.

2. We recommend monitoring fish entrainment rates with installed hydroacoustic transducers inside dam intakes throughout the year, which would provide an estimate of entrainment mortality with and without strobes operating.

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